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MENTAL FATIGUE

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Works in German

BY

MAX OFFNER

Professor in K. Ludwig's Gymnasium, München

Author of "Die Geistige Ermüdung"

Die Psychologie Charles Bonnets. A study in the history of psychology. Leipzig, J. A. Abel, 1893.

Willensfreiheit, Zurechnung und Verantwortung. Discussion of important concepts common to psychology, ethics, and criminal law. Leipzig, J. A. Abel, 1904.

Das Gedächtnis. The results of experimental psychology, and their application to problems of instruction and education. Berlin, Reuther & Reichard, (New Edition).

"The 'Value of Forgetting' is the subject which brings to a conclusion a book which should prove most useful. The usefulness, moreover, will be greatly increased by the bibliography and index which are appended." From *Mind*, January, 1910.

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Educational Psychology Monographs

MENTAL FATIGUE

A Comprehensive Exposition of the Nature of Mental Fatigue, of the Methods of Its Measurement and of Their Results, with Special Reference to the Problems of Instruction

BY

DR. MAX OFFNER

Professor at the Kgl. Ludwigs-Gymnasium at Munich
Author of "Die Psychologie Charles Bonnets," "Willensfreiheit, Zurechnung und Verantwortung" and "Das Gedächtnis"

Translated from the German

BY

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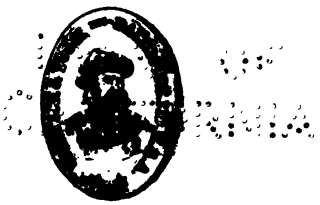

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AUTHOR'S PREFACE

I am glad to avail myself of the opportunity presented by this translation of my monograph on mental fatigue to make a few alterations and extensions of the original text and to preface it with a few words of introduction.

From the circumstance that the monograph hasmet with a favorable reception outside of Germany, I infer with satisfaction that, both in subject-matter and form of presentation, it is meeting adequately the needs of teachers and students whom I wish to supply with a critical, reliable, and intelligible guide through the extensive field of investigation of fatigue.

Of the great mass of material that is available—material that is difficult to gather up into a systematic and consistent treatment—I have mentioned, without intending to disparage the works that I have omitted, only those contributions that, in my opinion, are best fitted to introduce us to the more intricate study of fatigue investigation and its history. Naturally, I have given preference to German investigators, because it was the German teacher primarily that I sought to acquaint with the literature most accessible to him. The American teacher will be able, without much trouble, to choose satisfactory supplementary reading out of the numerous journals in his

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own language devoted to psychology, pedagogy, and school hygiene.

The terminology that I have employed will probably occasion no serious difficulties. If it does, further information about it and a more detailed justification of it may be found in my book on memory.

It will afford me particular gratification if my little book shall avail to contribute in some measure toward the furthering of that intellectual interchange that has for so long prevailed, to the mutual advantage of both, between America and Germany.

DR. M. OFFNER.

Munich, Germany.

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TRANSLATOR'S PREFACE

This translation of Offner's *Mental Fatigue* has been undertaken because the monograph collates, systematizes, and appraises a mass of scattered and to most readers inaccessible material that bears upon a schoolroom problem of unquestioned importance.

The author, in his introductory words, points out that the references are primarily adapted for German readers. To increase the usefulness of the book for American readers, I have, accordingly, at his suggestion, added to the bibliography a partial list of the books and articles available in English (Appendix I), and I have, in several places in the course of the text, inserted footnotes that are especially intended to assist those who desire it to gain further information concerning the several methods of testing fatigue, or to undertake for themselves experimental investigation in the schoolroom or the laboratory. For it is one of the merits of this book that its author makes no pretense at finality, but, on the contrary, is concerned to make evident the many gaps in our knowledge. And one of the objects of the translation is, accordingly, to stimulate others to contribute to this scientifically interesting and practically important aspect of experimental pedagogy.

No attempt has been made to render into English

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the terms descriptive of the German school system, but the reader will find in Appendix II an explanation of the German terms that have been retained.

In the preparation of this translation, I am specially indebted for assistance freely accorded by my colleagues, Prof. E. B. Titchener and Dr. L. R. Geissler.

GUY MONTROSE WHIPPLE.

Cornell University, March, 1911.

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MENTAL FATIGUE

INTRODUCTORY

In no field of work has experimental psychology come into closer contact with the practical problems of instruction than in the investigation of fatigue. Complaints against the overburdening of school children have been current for a long time. Because the earlier discussions of the problem, which were based upon general observations without the assistance of exact methods, were inadequate to settle the pros and cons of the dispute, experimental observation has been applied to its solution. The first contribution of this sort appears to have been a research published by the Russian psychiatrist, J. Sikorski, in 1879. There have followed, from year to year, further studies, so that in the last 30 years an extensive literature of mental fatigue has accumulated. The very extent of this literature, and the difficulty of getting hold of it, and the fact that thus far the investigations have not been brought to a perfectly satisfactory conclusion, may account for the circumstance that schoolmen have not, as a rule, shown as much interest in them as they warrant, in spite of their rather modest results. Indeed, it is not unlikely that the results would today be in better shape, that we should have, by now, made better progress in our solution of this complex problem if the schoolmen

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themselves, who have at their disposal the richest material for observation, had participated more than they have done in the solution of the problem. For hardly a single one of the investigations that have been undertaken by teachers has failed to make a contribution of more or less value. And so, to awaken the interest, and to bring about in any degree the co-operation in the study of fatigue of those in intimate contact with the activities of the school, cannot fail to be worth while not only for the school, but also for science.

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THE NATURE AND FORMS OF FATIGUE

What do we mean, speaking generally, by fatigue?

If we make no attempt at explanation and interpretation, but confine ourselves simply to the phenomena concerned, we designate by fatigue a condition of our organism that is developed by long-continued work, and that, in addition to other symptoms, is characterized in particular by a reduction in capacity for, and pleasure in, work. It is true, these symptoms may, for the time being, be counteracted, even cancelled, by antagonistic factors, so that the fact that the condition of the organism has been altered may be inferred only from other circumstances. According to the side of our psychophysical organism whose efficiency for work has been reduced—either by mental or by physical work—we speak of two forms of fatigue—of bodily fatigue as fatigue *for* bodily work, and of mental fatigue as fatigue *for* mental work.

And according to the nature of the work by which we fatigue our organism—either for mental or for physical work—we distinguish between a fatigue *by* bodily work and a fatigue *by* mental work.

We shall at first consider the fatigue of both sides of our nature, divided according to the nature of its cause, of the work which induces it.

Later we shall limit our consideration to the fatigue of the mental side of our organism (in which we are most interested), regardless of what kind of work has caused this mental fatigue.

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THE SYMPTOMS OF FATIGUE

Symptoms of fatigue induced by bodily work. The most important symptoms of fatigue by bodily work are well known. If we indulge in physical activity continuously and for a long time, if we walk or practice gymnastics or attempt mountain-climbing or perform other muscular work, after a certain time there becomes evident a considerable quickening and deepening of respiration and an acceleration of the pulse rate (Mosso, 107, 110; Verworn, 499*), save in the case of intense effort, where the opposite conditions are more likely to appear (Binet and Henri, 150), and at the same time there appears a rise in temperature sufficient to cause perspiration—at first in the members exercised, and then over the entire body, and finally a reduction of the capacity for work. We work more slowly, and hence accomplish less in a given unit of time than at the beginning; our gait, for instance, becomes slower and shorter, and also less certain, as mountain-climbers, in particular, find to their cost, and the lessened physical capacity affects not only the members that are directly exercised—here the legs—but other members also, as in walking the arms lose something of their muscular

*The Arabic numbers in parentheses here and elsewhere in the text refer, unless otherwise indicated, to pages in the references assembled in the bibliography at the end.

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energy (Mosso, 119). At the same time the feeling of freshness with which we started disappears. Gradually we come to feel dull and uncomfortable (the feeling of weariness). Furthermore, there is developed a disinclination for fatiguing, and ultimately for any kind of work, and a desire to end it; we long for rest. Every movement, every step, exacts greater effort, a greater expenditure of will-power. At the same time our mental processes become slower and less varied. Our conversation, accordingly, grows languid, trivial, and tends toward empty word-play; in the end we cease to talk altogether. We are also less sensitive to the stimuli of the outer world. Thus the beauty of the panorama makes little impression upon the tourist who is fatigued by the climb of the mountain; not until he has recuperated and regained something of his strength does it afford him satisfaction. In many instances excessive physical fatigue brings it about that objects that strike the senses make but little impression, so that the most beautiful scenery is quickly forgotten by people whose memory is ordinarily perfectly good. Even serious mental disturbances have been observed as a consequence of bodily exhaustion (Cf. Féré, 446 ff.; Mosso, 200). Physical work, then, unfits us for mental work as well. These and similar phenomena are psychic symptoms of physical fatigue, and show us that bodily activity results in mental, as well as in bodily fatigue. In the last resort, pain sets in, especially in those members whose activity is enforced, and it may come to pass ultimately that they refuse to function further, despite every exertion of will.

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The *physiological processes* concerned in the muscle at work, in so far as they have been determined at present, are of two sorts. We owe to J. Ranke of Munich (1865) our first information concerning them. In consequence of physical activity there are formed in the muscles certain substances, particularly lactic acid (the same substance found in sour milk) and acid potassium phosphate.

These substances or waste products thrown off from the muscles are poisons, or toxins (Mosso, 108 ff., 119 ff.; Verworn, 500). If one injects into a fresh muscle these products of the metabolism of a fatigued muscle, these fatigue-substances, as they are termed, then this fresh muscle, without having done any work itself, at once suffers loss of its contractibility and capacity for work. This Ranke demonstrated for a single muscle, while Mosso (119 ff.) strikingly confirmed the fact at Turin by injecting into a live dog the blood of another dog whose nervous system had been fatigued to a state of tetanus contraction by a strong electric current. And the same effect is produced—this is the second test—by the injection of dilute phosphoric acid and acid potassium phosphate (Landois, 612).

But, by flushing with dilute gas-free solution of sodium chlorid (0.7 to 1.0 per cent.), these substances are again eliminated, as experiments upon the muscles of animals have likewise shown. By this process the muscle for a short time regains its original capacity. And, indeed, energetic movement, *e. g.*, shaking the hand fatigued by writing, massaging fatigued limbs, as the runner often does, frequently suffices to render the muscle efficient for some time.

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The fatigue-substances—such is the most obvious interpretation—are, by these means, eliminated from the muscle. In the case of rest-pauses, the elimination is effected by the circulation of lymph and of arterial blood. To be sure, this elimination of waste products by the general circulation entails at the same time a gradual poisoning of the whole body, if the fatigue poisons that are thus distributed are not absorbed and rendered ineffective by other substances or eliminated from the body through the skin and kidneys. The question as to how this is accomplished need not concern us further. W. Weichardt (*Mün. Med. Wochenschrift,* 1904),* we may note, believes that he has at last discovered that the body forms an antitoxin against the fatigue-toxin, and he reports that he has succeeded in extracting this antitoxin and in rendering a mouse temporarily more resistant to fatigue by its injection. What value shall be attached to this interesting observation will be better known when it has been confirmed. At best, it offers only a means for partially overcoming fatigue, not for cancelling it completely, because the production of fatigue-substances is only *one* side of muscular fatigue—the *positive side.* There still remains the *negative side.* This, which is the more important, consists in the fact that the fat, and finally the muscle itself, is gradually absorbed during activity, for the consumption, the dissimilation of the materials of which the body is formed is, during activity, more intense than their assimilation (dissimilation and assimilation in the terminology of Hering;

*See also his recent *Ueber Ermüdungstoffe,* Stuttgart, 1910.—*Translator.*

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decomposition and recomposition in that of Hermann). That this using up of material is present in addition to the accumulation of fatigue-substance is shown by the circumstance that, in spite of repeated removals of the fatigue products, the capacity of a muscle that is subjected to repeated stimulation diminishes, and finally reaches zero.

Max Verworn (500 ff.), at Göttingen, has given an exact demonstration of this fact for the central nervous system by a celebrated experiment. The blood of a living frog was replaced by an 0.8 per cent. gas-free salt solution (*i. e.*, a solution totally lacking in nutritive substances) until the latter circulated instead of blood in the veins of the animal. Violent convulsions were then produced by a weak dose of strychnine, while at the same time the circulation of the neutral salt solution was discontinued. The powerful excitation and the activity involved in the violent contractions caused a rapid production of fatigue-substances. On account of the checking of the salt solution, these substances were not carried away, and they soon induced a condition of non-excitability of the nerves (rigor). So soon, however, as these substances were washed away with the salt solution, the excitability returned, though, it is true, it finally disappeared, despite continued flushing out of the poisons. Here, then, is fatigue without fatigue-substances! If now, however, the frog be flushed with oxygenated salt solution, he recuperates, and the condition of excitability is once more restored. Yet, still, after a time excitability again disappears, despite continued flushing with the oxygenated solution. Only when the frog has had injected in

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place of this solution one of defibrinated ox blood (blood that is freed of the solid constituents that are precipitated by coagulation, and that contains, in addition to oxygen, particularly carbon and sodium) does it maintain its excitability during many hours of strenuous activity.

Oxygen, carbon and sodium are, then, the substances that are especially required by living tissue for its activity. The consumption of these materials is the negative side of fatigue. Verworn prefers the term 'exhaustion' for this negative side, and understands by 'fatigue' merely the positive production of fatigue-substances—a usage that is followed by W. Rivers and by E. Kraepelin of Munich (*Psychologische Arbeiten,* I, 571; see also Hermann, 286). In any event, these two phases of the fatigue effect should be kept quite distinct in mind. To replenish these exhausted materials in muscles and nerves is the first task of nutrition and of rest, especially of sleep, when the use of material (dissimilation or decomposition) is so greatly reduced that the supplying of material (assimilation or recomposition) so far preponderates that there may take place an accumulation of surplus material—a storage of energy. Nutrition and rest accordingly have, likewise, two sides—a positive (the supplying of recuperative material) and a negative (the removal of fatigue materials).

Symptoms of fatigue by mental work. The course of fatigue by mental work is an analogous one. Efficiency gradually diminishes; at first qualitatively (we make more errors), then later on quantitatively (we accomplish less than we did at first). Our atten-

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tion exhibits marked fluctuations. We become more easily distracted, and find it progressively more difficult to maintain a line of thought and to bury ourselves in a problem. Children are then likely to begin to play during school work. The child, in such a case, may be said unconsciously to protect himself from fatigue by inattention, and, following Kraepelin, we may call his inattention a 'safety valve.' The observant teacher, who knows his pupils, possesses in this effect of fatigue a valuable sign of warning. Our range of attention, at the best, is circumscribed, so that things come more and more to escape our notice. Sense-perception functions both more slowly and with less accuracy; sensitivity diminishes. Discrimination for every type of perceptive content (acoustic, optic, tactual impressions, weights, etc.) is less certain and more subject to error; discriminative sensitivity is impaired. We learn more slowly as the work continues, *i. e.*, we learn a less amount and with less exactness in a given time, as is shown by the increase of errors revealed by subsequent testing. 'Dispositions' (in the sense used by Offner, 84) are less readily formed. In like manner, the reproduction of what has been previously acquired, *i. e.*, the effectiveness of the 'dispositions,' even of those that have been formed under the most favorable conditions, is affected by continued mental activity. Reproduction takes place more slowly and less accurately. Our fancy becomes impoverished, and our thoughts come 'in driblets' (Meumann, II, 122; Offner, 122, 142).

Finally, the capacity of the voluntary muscles is gradually affected, even though these are, during the

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mental activity, brought into play little or not at all. If, for example, bodily energy be tested by lifting a weight over and over again to a fixed height, or by contraction of the hand, repeated until the movement is no longer possible, then the time at which the contractions cease tends to appear much earlier after severe mental work than when we are mentally quite fresh (Cf. below, pp. 26 ff.). Movements executed after severe mental fatigue are also somewhat less certain and slower, as is especially noted in the case of accurately measureable movements of reaction, and, indeed, not seldom in the case of speaking and writing. Mosso (227, 254 f., and elsewhere) even detected uncertainty in gait after long and arduous mental activity in the laboratory and lecture room.

Moreover, the unconscious, or, as they are termed, purely physiological processes, are affected by fatigue through mental work. During such work, respiration becomes shallower and faster, but after it, deeper, as in rest; finally, in the case of excessive fatigue, respiration is again slower and shallower (Binet and Henri, 33ff.). The pulse grows more rapid, and may often increase until palpitation of the heart appears (Mosso, 223), while, as is well known, during bodily fatigue, pulse and respiration are accelerated, and the respiration, in particular, becomes deeper. In addition, on account of the increase in the blood supply of the active organ, the brain, there is a rise of temperature in the head with a concomitant reduction of temperature in the extremities, especially in the feet. Indeed, we all know the cold feet and hot head that we develop at our desk, and the college student who 'sweats up' for ex-

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aminations with a wet towel about his head is a familiar figure.

In consciousness there appear subjective symptoms, like those accompanying bodily work—at first a mood of indifference, then a disinclination to pursue the fatiguing work, together with the desire for a change. We are 'tired' of this work. Then a feeling of languor becomes evident, a feeling that we can't get hold of things, though we still want to. We feel weary for any kind of work (feeling of weariness). Finally, we feel exhausted, and crave nothing but rest and sleep. Then, not infrequently, headache follows—analogously to the soreness of the fatigued muscle; then restlessness and excitement, heightened sensitivity to impressions (hyperesthesia), especially to noises, nervousness, irritability, ill-humor and liability to passionate outbreaks. Children are apt to behave badly and to whine. All these are very important protective devices; they are warning signals that should admonish us to cease work and to seek nourishment and rest.

The *physiological processes* that we assume to underlie fatigue by mental work may be considered, speaking generally, like those for fatigue produced by bodily work, as a production of fatigue-substances and a consumption of constitutive materials, especially in the central nervous system. From this system, however, the fatigue-effect radiates, seeing that, on the one hand, fatigue-poisons from the actively working brain are gradually disseminated through the organism, while on the other hand, the substances in the rest of the body come more and more in demand, because no adequate replacement is

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afforded by direct nutrition. This view is, I grant, but an hypothesis, yet one that at present has a considerable degree of probability, and against which there is, at least, no serious objection.

It is scarcely necessary to say that the symptoms are not the same in all persons. Age, sex, temperament, state of health, nutrition, and, more especially, diathesis, play a considerable role. Neither is the picture of the symptoms of fatigue always the same in the same person. Thus, for instance, in most diseases, especially in nervous diseases and during convalescence, the phenomena appear more quickly, more intensely and more frequently than in a time of good health, and the same thing is true of periods of mental depression.

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THE MEASUREMENT OF FATIGUE

From what has preceded, it is seen that we have at our disposal two methods of undertaking the measurement of fatigue—of that reduction in capacity for work that ensues upon activity when inhibitory substances are generated, and when the consumption of the constitutent substances of the cells exceeds its immediate replacement by the processes of nutrition. First, the subjective method, that finds a standard of measurement in the subjective symptoms of fatigue, *i. e.*, in those that are conscious only to the fatigued person himself, and secondly, the objective method, that seeks a standard of measurement in modifications in the physiological functions and in the physical as well as the mental efficiency, *i. e.*, in modifications that are perceptible to others as well as to the fatigued person himself.

Unreliability for the measurement of fatigue of the subjective symptoms. It is evident that a subjective factor cannot be a reliable measure, however useful it may be as a signal. For our own mood, which not seldom varies quite independently of the consumption of energy, exercises an obvious influence. When we are happy we can perceive no weariness. When we are sad and depressed, a task to be done will all too soon engender that feeling

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that we are accustomed to interpret as weariness. If fear and anxiety attack us, we often forget all weariness, however much exhausted we had felt before.

A swallow of wine, a cup of strong tea or coffee, a few Kola pastilles banish the feeling of languor and give us for a time the illusory feeling of renewed freshness and undiminished capacity, even after the hardest kind of work.

And a glass of beer, on the other hand, may, before we have done any work, induce a feeling of languor and render us as unfit for work as if we had been through the most tiresome toil.

A short time after the chief meal of the day we are least fit for mental work, but most fit for bodily work, though we do not feel particularly disposed to undertake it.

There are, too, many individuals who feel weary, dull and ill-disposed at the outset of work, but who gradually become fresher, more efficient and cheerful as their work progresses. Yet there can be no such thing as actual fatigue when the task is just beginning. And there are yet other individuals who, under protracted work when the consumption of energy must have long exceeded the supply of fresh energy available at the time, experience no feeling of weariness, and keep at work until they suddenly give up, exhausted. In the former instance, therefore, there is the feeling of weariness without fatigue; in the latter, actual fatigue without the feeling of weariness. Hence the relation between the feeling and the psychophysical condition is anything but simple, and the unraveling of the threads that are here inter-

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woven, and the discovery of unity and regularity in this correlation, constitutes a special problem, whose solution depends upon the general view that we hold as to the nature of feeling.

The correspondence, then, between the subjective symptoms, the feelings, and the psychophysical condition is far too inexact and too ambiguous to afford us a basis for the measurement of fatigue. And for this reason no progress can be made in the understanding of the fatigue question so long as inquiry is mainly confined to this well-meaning but unreliable witness, the weariness feeling—a witness, what is more, that is inaccesible to experimental examination and impossible of exact measurement. Under these conditions, too, the discussions concerning the overburdening of school children can never rise above the level of conjecture and guesswork, and are wholly lacking in power to convince.

The objective procedure and the two chief groups of measurement methods. We must, therefore, look about for better measures, for symptoms that avoid this uncertain judgment of the fatigued person himself, for objective symptoms that are susceptible both of systematic experimentation and of mathematical treatment. These are, primarily, the physiological symptoms of fatigue that we have already cited. But certain psychical symptoms also turn out to be susceptible of determination and of measurement by objective, *i. e.*, by external, observation.

Accordingly, the objective method subdivides into two groups of measurement methods—the physiological and the psychological. The physiological

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group measures the decrease of mental efficiency—to the consideration of which we shall henceforth limit ourselves—by means of alterations of physical efficiency that it proceeds to test; in short, by tests of physical capacity, and by means of observing modifications that appear in specific physiological functions. The psychological group, on the contrary, confines itself to the psychical side, and observes and measures the decrease of mental efficiency that results from mental activity, either in terms of the changes that appear in the mental work itself that is being continuously pursued, or by means of tests of mental efficiency that are introduced at definite stages of the fatigue-producing work.

When there are a large number of subjects, particularly in schoolroom tests, there are two forms of procedure that are commonly followed. Either tests are given to the class as a whole—in which case there are needed several tasks of equal length and difficulty, a requirement that is hard to fulfil—or the class is divided on the basis of efficiency—putting those of like attainment into the same group—into as many groups as are wanted for tests, and one group is tested at a time, *e. g.*, as in the experiments of Winch and of Thorndike. This admits the possibility, under certain experimental conditions, of applying the same test-work at different stages of fatigue—a possibility of distinct advantage in extracting conclusions from the experiment. But, since this procedure reduces the number of subjects, and since, moreover, the same subject is tested less often—under some circumstances but once in a day—there is too much play given to the individual factor. And,

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at the same time, the chance of discovering this factor, of making allowance for it in the determination of averages or of basing conclusions on these averages is diminished or entirely lost. This is a disadvantage of this form of procedure which, to me, seems to more than outweigh the advantage that accrues from the absolute standard of measurement that it affords, unless the number of subjects or the number of experiments be sufficiently large to permit a change of the order of the groups, and unless the preliminary tests of mental peculiarities on which the distribution into groups is based be very precise.

The test methods rest at bottom upon two, or more often, upon three assumptions, the justification for which is, in the single case, usually probable, though not capable of absolute proof. The first assumption is that the work done really represents, both in quantity and in quality, the work that can be done under the conditions that prevail—that the work, in other words, is a real test of capacity.

The second assumption—one that is commonly, though not always made, and whose problematic nature is usually well recognized—is that the test of efficiency for the given type of work informs one also of the efficiency for other, particularly for related, types of work.

The third assumption is that the decrease of efficiency during the course of the work is essentially a fatigue phenomenon—an assumption that is indeed, in most cases, both very obvious and very probable.

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THE PHYSIOLOGICAL METHODS

The dynamometer. The decrease of muscular force, more exactly, of "the work that can be done by the muscle under voluntary contraction" (Eulenberg, 601), is a purely physiological symptom not only of bodily, but also of mental fatigue, as we have already shown. J. Loeb (1886) seems to have been the first to investigate "muscular activity as a measure of mental activity." Soon afterwards (1890) A. Mosso published his studies, "*Ueber die Gesetze der Ermüdung* ["On the Laws of Fatigue"], and his well-known book, "*La Fatica*" (1891), translated into German in 1892 [and into English, "Fatigue," 1904]. Up to that time the Collin dynamometer had been used for measuring muscular strength. This instrument consists of a steel oval, which, when gripped with the hand, indicates by a pointer the pressure in kilograms exerted by the hand. Ulmann's dynamometer is another form that can be used either for measuring pressure or traction.

These measurements that are secured by the use of dynamometers possess, however, little accuracy, in especial because the subjects are by no means apt to exert in an equal degree all the muscles concerned, so that when fatigue arises they may easily shift the groups of muscles and introduce into the later measurements groups of muscles that had relatively little

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share in the initial measurements. These and other objections have been emphasized by Hirschlaff (192): Gineff (39) and Claparède (200 ff.) have, however, expressed a more favorable opinion of the dynamometric method, while Clavière (*Année psychologique*, VII, 1901) and Schuyten have employed it for measuring fatigue.*

The ergograph. Having these difficulties in mind, Mosso constructed, on the plan of Helmholtz's myograph, a new instrument, known as the ergograph, and this piece has since been markedly improved by later investigators, *e. g.*, by Kemsies, Vaschide, Kraepelin, and others.

In the ergograph, the forearm and hand, together with the fingers, are firmly fixed in such a manner that the hand is extended, palm uppermost, and with only a single finger, usually the middle finger, left free. The flexion of this finger lifts a weight that is suspended by a cord, and the several lifts are inscribed accurately upon a rotating drum, producing a record termed an ergogram. The number of lifts that the subject can compass in a given period, and also the sum-total of the heights of the several lifts—for the automatic registration of which provision is made upon the best forms of the instrument—are taken as the measure of fatigue. The Belgian investigator, Mlle. Joteyko, has contributed particularly to the mathematical treatment and interpretation of the constituent factors of the ergographic

*The reader will find a fuller discussion of the dynamometric method and its results in the translator's *Manual of Mental and Physical Tests*, Warwick & York, Baltimore, 1910. Methods of conducting most of the tests of fatigue hereinafter mentioned may be found in the same volume.

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curve (see her *Lois de l'ergographie*). Philippe (Clavière, 204), made use of the ergometer, a sort of non-registering ergograph, in the use of which the experimenter himself must count the number of lifts.

It is, of course, always presupposed in this type of measurement that the subject of the test is firmly resolved to continue flexing his finger or gripping the dynamometer as long as he can possibly do so—a presupposition that is not susceptible of objective verification.

Furthermore, it is essential that the fastening of the arm and hand and the nature of the connection between the finger and the weight shall be absolutely constant in every test—a requirement that is obvious enough, but more easily stated than secured (Gineff, 47 ff.).

But, even if the assumptions be actually realized, the ergographs, even the improved patterns, do not afford the reliable results that had been expected of them. To be sure, the fact that the number of muscles put into play in the use of the instrument is considerably greater than the champions of the method suppose does not constitute a prohibitive defect, provided only that these muscles are always the same. But that is precisely the difficulty. It is true to a certain extent of all ergographs—as A. Hoch and E. Kraepelin (*Psychol. Arbeiten*, I, 380 ff.) and R. Müller (*Philos. Studien*, XVII, 65 ff., 13 f.) showed definitely for Mosso's instrument, and as Hirschlaff similarly showed for the dynamometer—that, as fatigue develops, the contractions radiate, until they finally involve the musculature of the shoulder blade, so that

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the presupposition of permanent isolation of a few muscles or permanent restriction of the muscular activity to a single controllable group of muscles cannot be attained.* And, what is more, the fundamental presupposition itself is not well enough established. The decrease of bodily efficiency is, indeed, a frequently-observed symptom of fatigue induced by mental labor, yet, if we leave out of consideration fatigue of an excessive degree with its consequences, it is not an absolutely uniform symptom, so far at least as experiment has, up to now, been able to determine. Not infrequently persons are found whose middle finger, to speak with a little exaggeration, cannot be completely fatigued at all by such movements as the ergograph demands, and this is equally true, even after mental work (Gineff, 10 f., 49 f.). And, even if we disregard exceptions of this sort, and have in mind only those persons—and they form the great majority—who are fatigued in body by mental work, even so there exists no clear and reliable correspondence between the reduction of bodily efficiency as measured by the ergograph and the reduction of mental efficiency. Kraepelin (*Psychol. Arbeiten,* I, 415, and *Ueber die Messung,* etc., 217) found that his subject performed more work on the ergograph from an hour to an hour and a half after the principal meal—*i. e.,* at a time notoriously unfavorable for mental work—than he did in the morning, and that he did best of all about 9 o'clock, after his supper. With children Schuyten (*On Vóor-en-*

*However, this objection has been almost, if not quite, completely met in the elaborate instrument devised by Bergström (*American Journal of Psychology,* XIV, 1903, 510-540).—*Translator.*

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Namiddags, 184) found by means of the dynamometer that their muscular strength was greater in the afternoon than in the forenoon.* Further, neither Kraepelin's pupil, T. L. Bolton (*Psychol. Arbeiten,* IV, 200, 219, 232) nor Gineff (51 ff.) was able to establish any definite relation between the duration of mental work and the values obtained from the ergograph. In fact, Bolton noted one person whose ergogram was not reduced, but increased, by two hours of mental work. In the same way, R. Keller of Winterthur (*Zeits. f. Sch. Hyg.,* X, 404 f.) found on one occasion a 50 per cent. increase of muscular efficiency after two hours and a half of forenoon instruction. In accord with these instances are the observations of Oseretzkowsky (*Psychol. Arbeiten,* III, 612), who reported a marked increase of muscular efficiency after severe work in memorizing, and, indeed, similar observations were in some cases made by Mosso (287).

Finally, the will, and, still more, the feelings and moods, may either reduce or increase the ergographic performance—a well-known experience that has been subjected to careful study by Féré (*Travail et plaisir*) and by Meumann (II, 97 ff.).

Hence the method of measuring fatigue by the ergograph, even if it should prove to be adapted for exact measurement of bodily efficiency, has turned out not to be sufficiently reliable for the measurement of mental fatigue, at least not sufficiently reliable for general use, though perhaps with some persons and

*A contrary result has, however, been reported in Smedley's investigation made upon public-school children at Chicago; see my *Manual of Mental and Physical Tests,* p. 96.—*Translator.*

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in some degree the correspondence that is assumed may obtain.

Measurement of fatigue by the respiration and by the pulse. Still less feasible are other very fluctuating physiological symptoms that are affected by many influences difficult of control, for example, to name the most prominent, the retardation and diminution of the pulse and the shallowing of respiration that frequently ensue upon mental work. Binet and Henri (33 ff.) have reported in some detail upon these methods of measuring fatigue. Under some circumstances, one can, to be sure, infer the presence of mental fatigue from the presence of these phenomena, but yet one does not always find them when fatigue is present, and even if they are to be thought of as symptoms of fatigue, still it is impossible to argue from their magnitude to the magnitude of the fatigue, since it is impossible to demonstrate any proportionality between the two.

Beating time. Closely related to the ergographic method is the method of beating time. This method, which has been recommended by W. Stern (*Diff. Psych.*, 117 f., 122 ff.), has been much used by M. Lobsien and W. A. Lay (especially 406 ff.) and has found particular favor in America (Gilbert, Wells) in tests of groups under the name, "the tapping test."*

This method, like the preceding, tests efficiency by resort to a physical process, which, like every bodily activity, is naturally influenced by mental factors.

*The tapping test of Gilbert and Wells, however, is not identical with the test of beating time here described, since in tapping the subject is instructed to tap continuously *at his maximal rate.* See reference, footnote, p. 24.—*Translator.*

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The subjects are asked to beat time upon a telegraph key, following some assigned rhythm, *e. g.*, a three-beat measure, at whatever rate best suits them. These movements are registered automatically upon a rotating drum (kymograph). The number and the rate of the movements are then used to measure the amount of psychophysical energy. For every person has his own rate—a natural individual rate of flow of his psychical life (Stern, 115, and Meumann, II, 117). The slower the tapping is done in comparison with this normal rate, the greater, so the inference runs, is the fatigue. Here, again, it is true that mental fatigue is not seldom accompanied by retardation of other activities—in this instance, of the tapping. But there is as little uniformity and certainty in the relation of this decrease of rate to increase of fatigue as there is between muscular efficiency and mental fatigue, or between the spatial limen and mental fatigue. Interest and will, mood, and so forth, play a part, and, in addition, the rhythmic tapping itself very often develops a condition of excitement that for the time being can completely cancel the effects of fatigue (Meumann, II, 101).

What is really measured in this test is only the speed of beating time—an action that is primarily physical in character—and, indirectly, through it the physical energy of the subject. This energy is naturally augmented during the period following meals. Thus one critic of the method, E. Meumann (II, 117, 136), found that the rate of beating time was accelerated after the mid-day meal, just as Kraepelin had demonstrated an increase in ergographic performance after meals.

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Measurement of fatigue by means of the range of accommodation of the eye. A. Baur, a training-school physician of Gmünd, Swabia, has made use of a new method of measuring mental or bodily fatigue in terms of muscular efficiency. By means of Scheiner's experiment, he observed the very sensitive muscle of accommodation, and found that the range of accommodation, *i. e.*, the distance between the far-point and the near-point, is increased in conditions of fatigue and exhaustion. Nevertheless, his investigations have not yet been carried far enough to permit the recognition of such a definite parallelism between increase of fatigue and increase of the range of accommodation as must be demanded for exact measurements of fatigue. We must await further comparative investigations to gain insight on this point.*

So far as the other physiological methods are concerned, this insight, as we have seen, has already been attained, and it has demonstrated that, despite the many valuable suggestions that these methods have afforded, they are so unreliable that, for the present, they can be disregarded in our search for exact measurements of mental fatigue.

*Since this was written, Baur has reported further results that disclose, seemingly, a very close relation between the range of accommodation and the condition of the central nervous system. See *Intern. Mag. of School Hygiene*, VII, January, 1911, 52-92.—*Translator.*

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THE PSYCHOLOGICAL METHODS

Methods of test-work. A better case may be made out for the psychological methods. In the first group of them the subject carries out some form of mental work as a test of his efficiency (test-methods). Some of these methods can be undertaken with very simple and very short tests of efficiency.

Esthesiometry. In this category belongs the determination of the degree of fatigue by the measurement of cutaneous sensitivity. The discrimination of two points, which forms the essential feature of the measurement, is a mental, not a physical process, as H. Griesbach in his later articles (*Inter. Archiv.*, I, 1905) has attempted, in opposition to Heller (*Wien. Med. Presse,* 1899) and others, to maintain. And it is a mental magnitude—whether we call it attention, as Griesbach himself originally thought (*Energetik,* 8, 87), or whether we name it mental energy, that is, the possibility that physical processes appear in consciousness (Lipps, 60 ff.; Offner, 44)—that is measured in this act of discrimination. It is, of course, true, as Motchoulsky especially emphasizes, that physical factors in the nerves of the skin are also operative. But so, also, are physical factors operative in the discrimination of colors, of pitches, of tone intensities, in the estimation of weights, of lengths, etc. In what mental pro-

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cess are they not, as a matter of fact, concerned? But no one would think of calling such psychophysical investigations physiological, even though they were first attacked by physiologists.

So, too, in this case, it was a physiologist, E. H. Weber of Göttingen, who discovered long ago (1834) that the shortest distance at which the contact of two points is still felt as separate, *i. e.*, as the contact of two cutaneous points, that the spatial limen, as the distance was named by Fechner,* varies at different regions of the body, and on different persons in the same region. The relative values of the spatial limen for different regions are, however, approximately constant for all persons.

Now, these liminal values are increased by physical work. Griesbach (*Energetik,* 1895) appears to have been the first to observe that, in a given individual, the limen is also increased by strenuous mental work. He found—and Eulenberg soon after confirmed the observation on himself (*Hyg. Rundschau,* VIII, 600) —that two closely approximated blunt compass points applied gently to the skin at the same moment are, as a rule, after fatiguing work, perceived as one point, whereas they had been still perceived as two before the work was begun. In general, the increase of fatigue goes hand in hand with the increase of the spatial limen, save that, under conditions of excessive fatigue, combined with mental depression and feelings of discomfort, there appears, for reasons as

*O. Külpe (*Grundriss d. Psych.*, 38 f., 350 ff. [see English translation, *Outlines of Psychology*, pp. 36 f. and 337 ff.]) and others have shown that this determination does not afford a liminal value in the strict sense of modern psychophysics.

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yet unexplained, a considerable diminution of the spatial limen. These compasses and like instruments, such as Eulenberg, Ziehen, Spearman, Ebbinghaus, Binet, Abelson [Jastrow, Titchener] and others have contrived for the same purpose, are called esthesiometers, and, accordingly, the spatial limen or the compass-point method is also termed the esthesiometric method.

Griesbach's subjects were pupils in the *Gymnasium* and the *Oberrealschule** (technical high school) at Mühlhausen, as well as teachers in training, and, in his later tests, teachers, soldiers and other adults as well. He secured his measurements from several regions of the body, *e. g.*, the forehead, the cheek-bone, the tip of the nose, the mucous membrane of the lower lip, the ball of the right thumb and the tip of the right forefinger. As he found that, in general, the sensitivity of these regions varied in like manner, he finally confined himself to the testing of a few regions—at times, indeed, to a single region, particularly to the cheek-bone, as being the most sensitive place.†

Nevertheless, this correspondence of the different regions held true only in a general way, as is shown especially by the comparison of measurements taken on symmetrical zones of the two halves of the body, and these, too, are neither structurally nor functionally absolutely alike. After more abstract ac-

*On the technical terms descriptive of the German school system, consult Appendix II.—*Translator.*

†Schuyten of Antwerp prefers to test that part of the cheek that lies vertically under the outer angle of the eye at the level of the tip of the nose, and, with good reason, recommends that measurements be taken on both sides of the face.

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tivities, *e. g.*, after grammatical exercises, memorizing, arithmetic, and a great part of mathematics, as, in general, after mental activity, it may be observed that, with right-handed persons, the measurements of the right side of the body—which, as is well known, has its centers in the left half of the brain (that hemisphere that is used in mental work, especially when thinking in, and by means of, words)—have yielded higher liminal values, even though the values were identical for the two sides before the activity. After activity that is predominatingly physical, on the contrary, the liminal values are apt to be higher on the left side. Finally, in the case of bodily activity under concentrated attention, these liminal values often differ but little from one another. With left-handed persons all this, as a rule, is reversed.

Griesbach's method found many adherents. Thus, his procedure was followed by R. Keller upon pupils in the *Gymnasium* and industrial school at Winterthur; by Th. Vannod upon pupils of a Bernese intermediate school; by L. Wagner in the *Gymnasium* at Darmstadt; by B. Blazek in a *Realgymnasium* at Lemberg; by Th. Heller upon feeble-minded children at Vienna, and by E. Schlesinger. These investigations led to results in the main accordant with those of Griesbach. More recently Bonoff, a school physician at Sofia, has worked with this method upon scholars of the *Gymnasium*, and Prof. P. M. Noikow of Sofia upon teachers and candidates for teaching, not to mention others, like Ferrari in Italy, Sakaki in Japan, Ley, Schuyten and Michotte in Belgium. A. Binet and J. Joteyko have also used and commended the method. (Cf. also Griesbach, *Int. Arch.*

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Schulhyg., I, 1905, and *Verh. d. IX Jahresver.*, 233.) And, last of all, there has appeared another successful champion of Griesbach's method in the person of W. R. Abelson, who has carried out very painstaking and extensive experiments upon pupils at Rennes and at London. The proof of a certain degree of correlation between the esthesiometric records and actual observation in the schoolroom has developed confidence for the method, and has attracted a good deal of attention.

On the other hand, the Griesbach method has been sharply criticized by the Kraepelin school. In the first place, Kraepelin (*Ueber die Messung*, etc.), and especially Th. Bolton (*Psychol. Arbeiten*, IV), on the basis of extensive laboratory tests that Bolton conducted with an improved esthesiometer—though, to be sure, upon a single observer—made it evident that the procedure advised and adopted by Griesbach and his adherents, when carried out in the hasty way that they had followed, was quite inadequate for an exact determination of the spatial limen, simply on account of the difficulty of applying the two points with absolute simultaneity, and with the same pressure in successive trials; that, on the contrary, an absolutely reliable determination of the spatial limen is such an elaborate undertaking that the method cannot be recommended for group tests. Secondly, and this is a more weighty objection, Bolton insists (196 ff.) that there exists no definite relation between degree of fatigue and magnitude of the spatial limen, although it is not unlikely, but ofttimes quite evident, that mental fatigue does have some effect upon the limen. As a matter of fact, discriminative sensitivity is often

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increased by emotional excitement, just as it is in the condition of hyperesthesia that follows excessive fatigue. "The experimental errors and the variations of the spatial limen set up by other causes are so great that, despite weeks of the most painstaking work with a subject trained in physiological experimentation, we have not been able to determine definitely the effect of fatigue upon the limen." Similar negative conclusions have been reached by other investigators, *e. g.*, by J. H. Leuba (*Psych. Rev.*, VI), who worked with adults of both sexes, and with college students, and who was especially careful to guard against disturbing conditions (thickness of the skin, blood supply, skin temperature, general physical condition and the like), and by Prof. C. Ritter of Ellwangen (*Zeits.*, XXIV), who undertook fatigue measurements upon *Gymnasial* students; by J. B. Germann, who employed but a single observer, and also by Gineff (15 ff.) and by Meumann (II, 91 ff.).

Nevertheless, it cannot be denied that the measurements of the decrease and increase of what we term the spatial limen, as secured with this method by Griesbach and many others after him, do show a degree of accordance that cannot be entirely attributed to bias, to autosuggestion on the part of the experimenter, or to that suggestion of the observer to which Tawney in particular (*Philos. Studien,* XIII) calls attention, even if this source of disturbance has been present in every instance. Again, the inaccuracy of procedure, for which Griesbach has been criticized, could at the most result merely in concealing, or in making less evident, the correspondence between the degree of fatigue and the spatial limen, provided such

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a correspondence were actually present; it could not have produced in so many instances an illusory appearance of a correspondence if no such thing existed at all. It must be added that the method of Bolton and others, as Griesbach shows in his later investigations (*Int. Arch. f. Schulhyg.*, I), is by no means free from criticism, and that the results in many instances are susceptible of another interpretation than that given them by Bolton. Moreover, the coincidence, to which we have referred, between the esthesiometric measurements and common observation, especially in the schoolroom, speaks for their utility as a measure of fatigue, more correctly as a method of measurement for one of the symptoms of fatigue.

And so it seems as if with this method we may, after all, come very considerably nearer to mental fatigue than with the ergographic or any other method that is based upon physiological symptoms; and this will be so much the more the case when we have succeeded in attaining technically satisfactory measurements—*e. g.*, in especial, absolute simultaneity of application of the compass-points, absolute equality of pressure in all applications (the more complicated instruments already make this possible), and equality of temperature of the instrument and of the skin—and when we have also succeeded in avoiding suggestion (which may affect the experimenter as well as the subject) and in eliminating what is known as the "paradoxical error," *i. e.*, the perception of two points when but one is applied.*

And when comparison is made of the values obtained in different regions of the body of the same

*See Gineff (15 ff.).

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person, it must be remembered that the richness of the nerve-endings in the different organs varies, as does also the thickness of the skin; and again, that one organ or one region of the body may be more practiced for this kind of discrimination than other organs or regions.

Finally, when comparison is made of the esthesiometric values of the same regions of the body in different persons, it must be remembered that, in this case, too, the thickness of the skin, the degree of practice of the person in general, as well as of the organ in question, condition individual differences, and that, furthermore, age, sex, ability to observe, sensory type, capacity for concentration, the general level of mental development, as well as external social relations (Vannod), all may be responsible for individual differences that must be taken into account before greater or lesser degree of fatigue, and thus of the fatiguability of the several individuals, can be determined in comparison one with another. All these values have, however, so far only an individual or relative value.

Measurements of fatigue by means of other liminal values. The difficulties that appear in this determination of the spatial limen in consequence of the variation in anatomical conditions in the same individual do not appear in the determination of other liminal values.

Meumann (II, 92) and Gineff (17) have, therefore, good warrant for asserting that we might just as well, and even better, use as an index of fatigue any other limen, *i. e.*, that we might measure fatigue in terms of the magnitude (which varies with the degree

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of mental freshness) of any other stimulus that is just perceptible, and that just arouses a sensory experience, or the similarly varying magnitude of the difference between any two stimuli that arouses two just noticeably different sensory experiences, *e. g.*, the limen for weak auditory or for weak pressure stimuli. This assertion, indeed, seems to be confirmed by Baur's experiments (*Das kranke Schulkind,* 175, note), for he found that the distance at which a watch must be placed in order that its ticking might still just be heard decreased as fatigue increased; similarly, he found symptoms of fatigue in the pupillary reflex, in the decreasing size of the field of vision and in certain variations in the recognition of colors, although these symptoms have not as yet been subjected to systematic study.

The kinematometer method. Nor have we as yet any thorough examination of what may be termed the kinematometer method. The kinematometer, or movement measurer, is an instrument constructed by G. W. Storring that indicates in angular degrees the magnitude of the movement of a member that is fastened in it. Meumann (II, 94) has worked with it, but his pupil, D. Gineff, gives (63 ff.) a more detailed account of the method. Gineff caused his subject, whose eyes were blindfolded, to execute for an hour or two a given form of movement, *e. g.*, a swing of the forearm over a horizontal baseboard, with the elbow as a fixed point of rotation. The extent of this movement, which was known as the normal movement, was regulated by two fixed terminal points or stops. Then he removed one of these stops, and directed the subject to make the movements that

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followed, the comparison movements, equal to the first or normal movement, as judged by the sensations set up by the movement, *i. e.*, to make the movements of such an extent that no difference could be detected between the 'feel' set up by it and the 'feel' set up by the normal movement. The more delicate the differential sensitivity for sensations of movement, the closer will the comparison movements approximate to the normal movement, or the smaller will be the error of estimation. In a fatigued condition, larger errors are made, *i. e.*, the comparison movements then exhibit greater deviations from the normal movement than in a fresh condition, because the differential sensitivity (sensible discrimination) for sensations of movement suffers from fatigue, just as we saw it to be affected in the case of other sensory experiences. In this instance, the error introduced by fatigue is not distributed evenly to either side of the normal movement, but there is a strong tendency to make the comparison movement shorter than the normal movement, or, in other words, to overestimate the former. The reason lies in this, that, in fatigue and exhaustion, as we all know, every movement is difficult and slow of execution; small movements are accompanied by a feeling of tension or activity (feeling of exertion of will) as intense as that that accompanies larger movements made in fresh condition. This feeling of effort, however, serves us as a secondary criterion of the magnitude of any movement that we make. Only occasionally do the comparison movements show a tendency to be much longer, viz., when the subject becomes cognizant of, and therefore strives to counter-

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act, that first natural tendency to make the comparison movement shorter.

On the basis of his experiments (unfortunately limited to a single subject), Gineff has reached the conviction that this kinematometer method is more reliable than the ergographic method. That his expectation will be confirmed is not improbable; in any case, the method is certainly simpler, and hence more easily applied in individual school tests, than is the ergographic method.

Method of time estimates. The estimation of time has been applied to the measurement of fatigue by M. Lobsien at Kiel (*Ermüdung u. Zeitschätzung*). A duration of one minute was filled by rapid metronome beats. The subjects (10-year-old pupils of a Kiel common school) had directly afterward to record their estimate of the length of this time. The average estimation, as computed from the total of the estimates, increased with some fluctuations from the beginning of the first hour, when it averaged 2.43 miuutes, to the last hour, when it reached 4.03 minutes. In view, however, of the notorious unreliability of children and of many adults in estimating time intervals, the estimation thus demanded on the basis of a single presentation of the object to be estimated seems to afford a very unreliable measure of fatigue; in any case, further and more extensive tests must be carried out, and upon adults as well as upon children.

The algesiometer method. The increase of sensitivity to pain, or the magnitude of the pressure that is necessary to arouse a sensation of pain (not a feeling of unpleasantness) at a given point, has also

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been taken by Vannod (*Fatigue intel.*) as a measure of fatigue. A prick-like pressure is applied to the skin by means of an 'algesiometer,' which is an instrument closely similar to von Frey's hair esthesiometer, and which consists essentially of a fine point and a scale that indicates the pressure of the hand upon the point, and consequently of the point upon the skin. In his experiments, Vannod found that at 8 o'clock, before instruction began, a pressure of 45 grams set up a pain sensation, whereas at 10 o'clock, 39 grams, and at noon only 29 grams sufficed. Swift has carried on similar tests in American schools, and Vaschide has confirmed Vannod's report. Binet (*Année psychologique,* XI), however, reached directly the opposite result, viz., that fatigue decreases, not increases, pain sensitivity (Cf. Claparède, 199 f., and Meumann, II, 109).

It must be repeated that in all these cases, with the exception of these last—as to the real nature of which we have as yet insufficient knowledge—what is measured is not so much mental fatigue itself, as rather a mental activity that is essentially conditioned by the degree of attention that is given to it. We are dealing, then, with a measurement of attention, the reduction of which we regard as the result of the work that has been performed. But it is evident that the measure of the attention applied to a given piece of work, or of the mental energy displayed in it, is conditioned not only by the amount of mental energy available at the time, but also by other factors, such as feelings, moods, general disposition, inclination, and the like. However, these supplementary factors are not subject to regular

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daily or weekly variations corresponding with the amount of work done at the time, but are quite variable in their appearance, so that, as investigations increase in number, they assuredly tend to be eliminated. The fund of mental energy, on the other hand, is the most important factor that conditions attention and psychical activity in general, so that any reduction in it during or after a period of work becomes very clearly and very uniformly evident. On this fact rests the applicability of discriminative sensitivity to the measurement of fatigue.

The measurement of fatigue by the measurement of the duration of mental processes. We have already made reference to the fact that the duration of mental processes is affected by fatigue. The principle has been turned to account experimentally by Keller. In studying the development of fatigue during lengthy gymnastic exercises, he had his pupils read words at a fast rate, and found that the average time of reading was increased by 13 per cent. for words and by 16 per cent. for syllables, in comparison with the average time in a fresh condition: even when the same words or syllables were used, the time was increased by 10 and by 9 per cent., respectively. In a similar manner, Lobsien (*Unt. u. Erm.*) sought to detect fatigue by the rate of reading and the number of errors committed.

Following the demonstration by Axel Oehrn (*Psychol. Arbeiten,* I) that speed of mental activities is reduced by fatigue, S. Bettmann (*Psychol. Arbeiten,* I) employed the more refined methods of the laboratory to determine the time necessary to react to a presented impression or stimulus with one of two

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very simple movements, in accordance with a prearranged combination of stimulus and movement—in other words, to measure the time of the simplest 'choice reaction.' He found that this time was longer when the subject was fatigued, and that this retardation was more evident after mental, than after bodily fatigue. Although Bettmann has called special attention to the sensitivity of this method, it does not seem, up to now, to have been employed further for the determination and measurement of fatigue, so that we cannot say at present whether or to what extent it is feasible for more exact measurements. In any event, the fact that, in the determination of fatigue by means of computation and other similar tests, the speed of work increases at first, and often continues to increase, though the quality is reduced, should warn us to be quite cautious in generalizing about the relation between the speed of mental activities and fatigue.

The method of test-problems in the narrower sense. The discrimination of two points on the skin, the perception of faint sensory stimuli, the comparison of the extent of two movements and similar processes are all mental activities that are used to ascertain how much of mental energy remains after some other form of mental activity. The method of test-problems in the narrower sense is based on the same principle. In it, a test is introduced during or after the mental activity that is creating fatigue. But this test is now far less simple, less limited in its demands, less dependent on physiological factors and more akin to the fatiguing mental activity that it measures than is the test of discriminative sensitivity, etc. The

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test-work consists chiefly of such tests as taking dictation, computing, counting letters, and other similar activities which involve a series of mental processes of a predominatingly intellectual character, like those that constitute the higher mental processes in general.

This method had its inception in the common observation that hard mental work renders us disinclined and unfit, at first for the kind of work we are doing, then for similar work, and finally for any sort of mental exertion. That is to say, we are in a state of general fatigue. Nevertheless, we have reason to suppose that this general reduction of mental efficiency does not affect all phases of mental activity equally, but rather in accordance with the degree of similarity—that, in other words, the mind is the more fatigued for a given form of new activity, the more this new activity resembles the original fatigue-producing activity.*

It follows that these tests of fatigue that prescribe a form of work that is as similar as possible to the fatigue-producing activity, particularly to school work, really get at mental fatigue from more sides than do such tests as esthesiometry and the like.

Still, they do not, by any means, get at it from all sides, because a form of test that should be fully equivalent to the activities involved in studying and in school work generally would itself be so complicated that it would be impossible to evaluate it exactly, especially to determine and compute the errors, and hence impossible to compare the different tests;

*The disputed question of specific versus general fatigue must be deferred for extended discussion in a subsequent section.

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moreover, it is impossible to devise absolutely equivalent test-problems. Accordingly, if we want a form of test that shall permit of ready quantitative treatment, and that shall at the same time be exactly equivalent to the fatiguing work, we must simplify the fatiguing work, *e. g.*, by the use of dictation, simple computation, and the like. By this plan, we secure perfect comparability between the test-material and the fatiguing work; on the other hand, we lose touch with practical life, because the mental fatigue that we wish to measure is commonly the result of a much richer and more elaborate mental activity.

Schoolroom tests of fatigue seek a path between these two extremes. The younger a class and the simpler the mental work that is required of it, the nearer can the test approximate to the fatiguing school activity. But the more advanced the class and the more manifold and complex the work that is done by it, the less can the test be made to approximate to this more elaborate fatiguing work.

The first investigator to employ considerable amounts of work as test-materials for measuring fatigue was the Russian psychiatrist, J. Sikorski. He had pupils write from *dictation* for a quarter of an hour, both early in the day, before school work began, and later in the afternoon, after school work was over. He found 33 per cent. more errors in the second exercise. It is understood, of course, that here, as in other experiments of this kind, it is not a question of errors that spring from lack of knowledge, but only of errors that spring from slips of attention. Naturally, Sikorski's method, like the first trial of any such experiment, is susceptible of

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improvement: it served, however, to break the ground, and those who followed him, like Friedrich at Würzburg and Bellei at Bologna, have learned how to avoid his difficulties. Yet there remains the great difficulty of arranging material for dictation that really presents uniform difficulty for the pupils, for unity of the standard of measurement is a prime necessity.

To circumvent this difficulty, H. Laser (*Geist. Erm.*), following Burgerstein's example, selected *simple computation* as a test-material. He had his subjects, boys and girls of the middle classes of a Königsberg *Bürgerschule,* perform easy examples in addition and multiplication for 10-minute periods and as rapidly as possible. The periods he arranged to fall at the opening of the morning session and at the end of each one of the five following school hours. He discovered a rapid increase in the total amount of computation performed by the several classes during the school session. This increase, however, is to be explained as due, not to any augmentation of mental energy toward the end of the session, but partly to the development, during the work, of practice in computing, and partly to the overcoming of the mental inertia that prevailed at the outset. On the other hand, the increasing fatigue of the classes found its expression in the increase in the total number of errors (except in the final period) and of corrections (made by the pupils themselves), and in the decrease in the number of pupils whose work was without error. These results of Laser coincide substantially with those obtained by Burgerstein by another form of computation test, to which we shall refer later on.

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Ebbinghaus (*Neue Methode,* etc.) also used this method, and obtained similar results. Computation has been tried, likewise, by Richter, Friedrich, Kemsies, Dankwarth, Teljatnik and Belleĭ.*

The query may, however, be raised whether this application of the computation test for 10 minutes or longer is not unwise, for, as Ebbinghaus noted, computation develops a considerable practice-effect in a period of this length, and again, the computation itself becomes a source of fatigue. Moreover, ennui, with consequent carelessness and loss of interest, brings it about that the quantity and quality of the computation cannot be regarded as an unambiguous expression of the fatigue induced by the school work that has just preceded. But, by both shortening the duration and increasing the difficulty of the computation exercises, it seems as if a measure of fatigue is discovered for us here, though one that can be employed only along with others, because it involves only a specific and limited form of mental activity.

What is called the *memory method,* as used by Ebbinghaus (*Neue Methode,* etc.), and later on by the Russian experimental psychologist, Netschajeff, by Schuyten, and by others, seems to be less applicable in the schoolroom. In Ebbinghaus' experiment, series of one-syllabled digits (the numbers 1 to 12†), arranged to supply two series each of 6, 7, 8, 9, and 10 places (*i. e.,* 10 series in all) were read aloud, with a single reading for each series, at the beginning and at the end of a school period. The pupils, who in-

*For methods and results see also reference, p. 24, note (Ch. IX, Test 35).—*Translator.*

†The German term for eleven is monosyllabic.—*Translator.*

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cluded *Sexta* to *Untersekunda* forms [ages 8 to 18] of a Breslau *Gymnasium* and some classes of a higher girls' school, were then asked to write down each series as accurately as possible. Fatigue was to be indicated by the number of errors. But, in almost every case, the number of errors decreased toward the end of the school session. Here, then, the effect of fatigue was concealed by practice, by the confusion incident to writing the digits, and perhaps also by the method that Ebbinghaus chose for computing the errors. And even if this method did afford a fairly exact expression of fatigue, it would need, for the same reasons as were cited for the computation method, to be supplemented by some method that would afford contact with other phases of mental activity, since the retention of series of one and two-place numbers is quite as limited and specific a form of work as is long-continued adding and multiplying. The same thing might be said, too, of tests of memory for series of words, as employed by Ritter and Teljatnik, and of memory for sentences, as employed by Januschke.

What has been termed the *'completion method'* was invented by Ebbinghaus (*Neue Methode,* etc.) for the same purpose of testing fatigue. There were laid before the pupils prose texts, as nearly as possible of the same difficulty, in which many of the words were omitted entirely, and in which only portions of others, *e. g.,* some syllables or only the first letters, were given, and the pupils were instructed to fill out the gaps so as to make sense and with due regard to the number of syllables demanded. Five minutes were allowed. One text was taken from Net-

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tlebeck's Description of the Siege of Colberg. A single paragraph will suffice to illustrate the plan. Wh.. Willy ... two ..... old, he .... red farm-h..... ..th . yard .. front .. .. The dan.... ... were .... th... there; so that ... . lo.... yellow instead of .....* The nature and number of the errors and of the corrections were to be taken as an index of fatigue. The result was not very clean-cut: there appeared an increase in the quantity of work done, *i. e.*, in the number of elisions supplied, in the upper classes, but a decrease in the lower classes. *Sexta* and *Quinta* [9 to 11 years]. The quality of work did, indeed, become poorer in all classes, although the maximal number of errors was by no means made in the last study period. The decline in quality was also much more rapid in the lower than in the higher classes.

The method is, of course, open to improvement. Ebbinghaus is quite right, for instance, in concluding after his experiment that the time allowed for supplying the elisions was too long. His experiments, it must be remembered, were all preliminary experiments, and, unfortunately, the test proper that was to follow them was never carried out. Moreover, despite Ebbinghaus' proposals (*Neue Methode,* 47 f.), the most serious difficulty still remains—that it is even less possible than in the case of dictations to work out any very large number of texts of equal difficulty, or to recognize and make due allowance in computing results for either these un-

*This example, from the translator's *Manual*, p. 448, is substituted for the German text. Blank forms for conducting this test may be purchased of C. H. Stoelting Company, 121 North Green street, Chicago.

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avoidable differences in the texts or for such differences as depend on the individuality of the pupils tested.* These difficulties, coupled with certain of those that have been cited in connection with the methods previously discussed, will interfere with the use of the Ebbinghaus method in extended school tests. It has, moreover, been tried thus far only by Bellei,† though it has the advantage over all other methods of appealing to quite varied phases of mental life, yet not, of course, to all phases.

A more difficult form of the completion method is used by some French investigators. They give the subject a number of words which are arranged together and written down as a whole in such a form as to make sense. The method used by Emily Sharp,‡ in which as many sentences as possible are constructed from a limited number of words, is of similar kind (Cf. Gaupp, 126). These methods have the evident advantage that they engage a considerable part of the subject's mentality, but they have also the defect that they put at a disadvantage subjects of lesser ability and of little practice, and that, furthermore, even when merely inserted as tests, they are themselves extremely fatiguing.

When these objections are considered, the dictation and computation methods must, after all, be

*Cf. the criticisms of Lobsien, *Päd. Psych.*, II, 365 f., and Binet, 316 ff.

†This statement is not strictly accurate. Ebbinghaus' method has been tried by Wiersma (1902), by Terman (1906), by Krüger and Spearman (1907), and with some modifications by Lipmann and Wertheimer (1907), though only Wiersma was directly interested in testing fatigue by its use.—*Translator.*

‡See *American Journal of Psychology*, X, 1899, 329-391; also reference, footnote, p. 24 (Tests 46 and 47).

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given preference over the completion method, since they are simple methods, but nevertheless have fewer defects. Especially are they to be preferred when their task is made somewhat more difficult, as for example, the form of computation test employed by Kemsies (*Arbeitshygiene der Schule,* 7), and by Teljatnik, in which the computation is done wholly mentally, and only the result written down. This plan has the further advantage of reducing the physical work of writing, and thereby lessening the chance of introducing some bodily fatigue in the computation itself.

Yet, the chance of inducing fatigue in this way needs hardly to be considered when dealing with maturer pupils, and especially with adults. With such subjects, more difficult computations may be employed with success, as Winch has shown in the case of evening school pupils, 15 to 27 years of age.

The advantage of easy administration and of a certain breadth of activity—though not, of course, of universality of appeal—attaches also to a method used by Ritter (*Zeits.,* XXIV, 424 ff.).* In this (the *cancellation method*), specified letters or words are to be crossed out or cancelled on a given printed text as rapidly as possible. The assignment might be, for example, to put a vertical mark through every R and *r* and a horizontal mark through every form of the definite article.† Only two minutes are allowed

*This method appears, however, to have originated in the work of Bourdon (*Revue philosophique,* 1895). Ritter's article appeared in 1900. For a more extended account of it see my *Manual of Mental and Physical Tests,* pp. 254-270.—*Translator.*

†In German the article is declined, and hence appears in several different forms.—*Translator.*

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for one such test. The difficulty with this interesting method lies in the selection of texts that shall afford, for a full series of tests for a day, not to speak of a week, an approximately equal distribution of the letters or words to be cancelled.* The rapid development of practice also tends oftentimes, at the beginning, to conceal the effect of fatigue.

Still simpler is the *copying method* employed by M. C. Schuyten, the conductor of the Pedological Institute at Antwerp (*Arch. de Psych.*, IV, and *Paed. Jaarb.*, VI, 160 ff.). The teacher writes on the blackboard a certain number of combinations of the letters *a, e, i, o, u, r, v, n.* The pupils have five minutes in which to copy them. The number of errors and [self-made] corrections gives a measure of attention, and hence of the mental efficiency prevailing at the time, and the variation in this number at different hours of the day serves as a basis for estimating the course of the fatigue developed by the day's work.

Perhaps the most suitable method, both because it exacts activities that are neither too easy for the subjects nor too difficult for evaluation by the experimenter, and because it entails manifold forms of mental activity and so does not become monotonous and irksome,† is the *combined method* by which Teljatnik‡ tested 25 *Volksschule* girls, averaging 9 years of age.

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*Several plans for meeting this difficulty are now available. See *Manual*, 256-7.—*Translator.*

†The method, however, does take considerable time, some 20 minutes, when used for testing fatigue, and may thus itself become a source of fatigue.

‡See Teljatnik's report of his own researches as prepared for Burgerstein's *Handbuch der Schulhygiene*, 2d ed., pp. 462 ff.

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Every experiment was subdivided into four parts. The first of these tested attention. The girls were asked to count the letters in each of the first five lines of a page of their readers, and to write down the five sums upon a sheet of paper. They had next mentally to add, or to substract, several pairs of two-place numbers that were written for them on the blackboard, and to write the answers on their papers. To test observation, or direct retention, as Meumann likes to term it (or the capacity for immediate reproduction, as I prefer to say—*Gedächtnis,* 129), either six one-to-three syllable words or four one-to-two place numbers were used. These were either recited by the teacher and then repeated by the pupils in concert, or were written, shown, and then erased; in either case, the pupils had immediately to write down as many of them as they could remember. Recollection, or, more accurately, recognition, was tested by handing to the pupils sheets containing 100 words and 50 figures, among them those that had been previously used in the test of immediate reproduction, and asking them to underline the words or numbers that they had heard (or seen). Since, however, every act of recognition is conditioned by two factors—the disposition (tendency) and the incitement of the disposition (Cf. Offner, *Gedächtnis,* 108)—it follows that the recognition can fail, either on account of insufficient strength of incitement, despite a very strong tendency, or on account of a feeble tendency (poor impression), despite a strong incitement. These two factors, then, must be considered independently of one another, because it is not certain whether the two are equally affected by fatigue.

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This four fold test was applied at the beginning, at the end and twice in the course of a school session that ran from 9 to 2 o'clock, and that was broken by one long and several short pauses. By a special method of treating the data, Teljatnik derived from the four forms of tests an average value which he termed an "index of general capacity for work," and which he used to measure mental fatigue, together with the effect of pauses in the school work (some occupied in games, some spent in absolute rest), and other similar phases of the problem.

We may, perhaps, think of better specific tests than these; we may criticize the plan of combining values derived from the separate tests into a single one that conceals the differences in the development of the component factors; nevertheless, Teljatnik's method seems to be the one that has, thus far, made the most manifold appeal to mental life, and at the same time the one that is characterized by the greatest ease of administration and evaluation.

If we take a general survey of these experiments with various forms of tests, from the method of Griesbach to that of Teljatnik, we see that, despite many defects that may perhaps be remedied, and many difficulties that are inevitable, they supply us, beyond any doubt, with serviceable average values (particularly when, by frequent repetition, the errors are gradually eliminated by the law of large numbers), and afford reliable information as to the effect and the degree of fatigue, and that they may, therefore, be significant for us in the regulation of our work. These methods are also, so far as we can see, the only ones that can at the present time be ap-

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plied in schools, and so be of direct utility for practical schoolroom service.

Their theoretical value is, nevertheless, limited. These forms of test-work do not permit us to follow the course of fatigue accurately and step by step, else the fatiguing work would be so frequently interrupted by the inserted test-work that the effect of the former would be concealed, since the test-work itself would induce a high degree of fatigue.

Method of Continuous Work

It was, therefore, a happy thought to use the fatiguing work as test-work, to observe uninterruptedly the changes in quantity and quality of performance effected by the fatigue-work, and to take these changes as an index of the fatigue or of the decrease of mental efficiency caused by the work.

In this method, then, it is the continuous work itself, not bits of test-work applied at different times, that indicates to what extent and how rapidly mental efficiency is affected by the work.

It is clear that any continuous mental work of a complex nature, *e. g.,* the reading and assimilation of a paragraph from Kant's *Critique of Pure Reason,* the working out of mathematical problems or the prosecution of botanical observation and experiments—that such complex work would exclude the possibility of a detailed and exact determination of the effect of fatigue. For this purpose such simpler mental processes must be selected, processes that are not only characterized by a high degree of uniformity, but that also permit the quick recognition of the effect of fatigue. The course of such an activity, *e. g.,*

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two-hour adding of one-place numbers, may also be shown in graphic form. A horizontal line is divided into 24 parts, each one of which (for the two-hour test just mentioned) accordingly represents a five-minute period. The additions made in each of the five-minute periods are then indicated by a line of the proper length erected as a perpendicular to the base-line. By joining the tips of these perpendiculars, we obtain a line that is known as a curve of work.

This method was used for the first time by the Austrian schoolman, L. Burgerstein (*Arbeitskurve einer Schulstunde*), when, in 1891, he studied the course of fatigue within a single school hour. He caused his pupils, boys aged 11 to 13 years, to perform easy examples in addition and multiplication, in periods of 10 minutes each. A pause of five minutes was introduced after each of these work-periods. In this case, he found that, on the average, the number of examples performed increased from one quarter of an hour to the next, perhaps on account of augmenting practice, or, toward the end, from anxiety of the boys lest they should not be ready, or because at the start they were working under an inhibition that was only overcome by the work itself. There were, however, more errors and corrections made as the work went on.

In a similar, though much less extended experiment, using forms of Latin verbs as test-material, H. Merian-Genast, in the *Gymnasium* at Jena (Cf. Richter in *Lehrproben,* XLV, 8, note), obtained similar results. This method is feasible for school use.

So far as Burgerstein's results are concerned, we

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may call attention to his rather questionable computation of the errors (Binet and Henri, 300; Ebbinghaus, 24), and we should note that the results cannot be interpreted without qualification as an indication of the fatigue-effect of an ordinary or normal school hour. For school work is hardly ever so extremely uniform in character, nor does it ever require uniformly sustained attention of the sort exacted in these computations, which, moreover, were carried on under stress of maximal speed. This criticism has already been urged, and with right, by Richter, Uhlig and others, particularly against Kraepelin's work. Demands like those in these tests are made upon the pupil at most only when he is doing 'sight work' or school tasks, or when he is actually being questioned, and the other pupils are then less actively engaged. Moreover, continuous computation of an hour's duration is a monotonous work of a kind such that, after a short time, ennui or aversion, or at least indifference, appears, and this must be overcome by plucking up fresh courage for attentive work: these circumstances are naturally fatal to uniform work of sustained quality, while, despite fatigue, the speed of the work is increased by practice (Cf. Ebbinghaus, 6; Binet and Henri, 302). But even if these difficulties did not exist, we should still be unable, as we have already pointed out, to infer positively, and as a matter of course, that fatigue followed the same line of development in other forms of mental work as it does in the case of computation. That must first be proved. For these reasons, Burgerstein's results, like those obtained with his method by others, *e. g.*, by Marion Holmes (Pedagogical Seminary, III) with

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American students, have in every case only a limited significance, namely, for that particular work upon which they were based.

Within this limited field, however, the method of continuous work undoubtedly affords information of value so far as it applies, and its usefulness for school practice becomes greater in proportion as the task used for experimentation resembles the tasks of the schoolroom itself. The best plan is simply to use school work itself as the basis, though this, to be sure, can be done only in the earlier grades. This plan has been tried by L. Höpfner (*Zeits.*, VI, 194 ff.), who conducted a dictation test with a class of boys of the average age of 9 years. This test consisted of 19 sentences, each one containing approximately 30 letters. Each sentence was read to the class once, then repeated once by a single pupil, and finally repeated by the entire class. After this, the children were required to write the sentence from memory. The work in this way took two hours in all. Höpfner discovered a general, though very irregular increase in the number of errors from sentence to sentence. His psychological analysis of the errors showed that the longer the dictation continued (and hence the more wearied the pupils), the more prevalent became errors due to the displacement, by colloquial speech, of the literary phrases learned in the classroom. It is, then, the later acquired bits of knowledge, the more recent associations, that fail first—that first show the effect of fatigue—while the older acquisitions, the words, grammatical forms and expressions of colloquial speech that have been learned earlier, and hence much oftener used—in short, the older as-

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sociations—are thereby brought into function as substitutes for them.

The advantage of Höpfner's method over that of Burgerstein consists in the fact that in it a regular school activity has been studied for its fatigue-effect. And two further points of advantage are that, since a real test is in operation, the pupils, of their own accord, exert their attention to the utmost—indifference and negligence cannot, therefore, enter as disturbing factors—and that efficiency cannot be so markedly augmented by practice during the test, as is so plainly the case with computation-work. There is, to be sure, one source of trouble even in this test, viz., the task of securing material for dictation that shall offer equal difficulty throughout.

The method of continuous work has been used with special success by Kraepelin. In addition to the counting of letters, reading, and the committing to memory of series of digits and syllables, he has favored the use of the method of the continuous addition of one-place numbers, because adding has the merit of being, after all, one of the higher forms of mental activity, while at the same time it is psychologically far more uniform than other mental activities. Moreover, verbal imagery and articulatory movements play a relatively minor rôle in it. Kraepelin has worked out a simple procedure for this method. The subject is required to add, for a long time (sometimes several hours), numbers printed in vertical columns in a specially prepared note-book.* Whenever the sum exceeds 100, the hundred is

*American readers may purchase such prepared forms of C. H. Stoelting Company, 121 North Green street, Chicago.—*Translator.*

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dropped, and the remaining units are carried on for further additions. A signal bell rings every five minutes. As soon as the subject hears it, he makes a mark after the last digit that he has added. By this means it is easy to ascertain, after the experiment is finished, just how many digits have been added by each subject in each five-minute period (Kraepelin, *Geistige Arbeit,* 4th ed., 8). This form of the method of continuous work is, to be sure, ill-adapted for use in the school, as Kraepelin himself admits (*Ueberbürdungsfrage,* 13), but he and his followers have, by its exploitation, done pioneer service in the investigation of fatigue.

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RESULTS

Various factors in addition to fatigue, that determine efficiency.

To Kraepelin and his followers we are primarily indebted for the insight that we possess into the course of long-continued mental work. And this brings us to discuss the *results of the investigation of fatigue.*

These investigations have shown that there are several factors, several psychophysical phenomena, that are more or less commonly present in this kind of work; that these phenomena are consequences, just as fatigue is a consequence, of persistent mental work, and that they, too, influence the outcome of the work, influence our performance. Their influence is however, largely opposite to that of fatigue, so that they reduce or cancel the fatigue-effect, in part, and render it for a time imperceptible. These same influences are also operative in muscular work (Oseretzkowsky), and must, if we would avoid a false interpretation of the results, be kept constantly in mind in all measurements of fatigue or measurements of work done.

Practice. In the first place, there is *practice.* Whenever we continue or repeat an activity, the consequence is that, to a certain extent, the activity is carried out progressively more easily, *i. e.,* with a

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lesser expenditure of energy, with a lesser degree of attention, and also both more speedily and more accurately, *i. e.*, with fewer mistakes and more economically, in that it constantly comes nearer the way we wish it to go to accomplish the result that we desire. Although the work done should relatively soon suffer quantitative, or at least qualitative impairment on account of the gradual rise of fatigue due to the consumption of the available supply of psychophysical energy and to the fatigue-substances, we soon find, on the contrary, a distinct and fairly persistent augmentation, both quantitative and qualitative, of the work done. We learn, while we are working, to master our tasks better: after a short period of work, often, in fact, after a few minutes, we do arithmetical work more accurately, and particularly more rapidly than we did when we began. This process of progressive improvement of performance we may term the *concurrent practice-effect*, and the amount by which, in a specified time, the performance excels the initial performance, we may term the *concurrent practice-gain*, or the *practice-result*.

This practice-effect does not, as one might be inclined to expect, increase in proportion to the duration of the activity that is being practiced, but is greatest at the beginning, and becomes smaller and smaller as the activity continues, most probably just in consequence of fatigue. If the work be divided into a number of sections, each section will be found to have its practice-result or practice-effect, but it will be less from section to section.* Yet, the per-

*Cf. in this connection my discussion of the significance of repetitions for impression (*Das Gedächtnis*, esp. pp. 47-59).

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formance will still show improvement until fatigue tips the scales against it, so that the work done is more and more reduced, at first qualitatively and then quantitatively, until, as the feeling of fatigue grows progressively clearer and stronger, it finally falls below the level at which it started. Now, the total practice-result of these several periods of work is not a permanent possession that remains as large as it was when it was set aside; on the contrary, the condition of practice begins to wane as soon as the practicing activity stops. And, again, this process is not proportional to the time elapsed, but is rapid at first, then slower and slower, and often the state of practice remains perceptible for a surprisingly long time (Cf. Offner, 103 ff.). This *residual skill,* this *practice-gain that persists,* can be recognized in the facilitation of the activity that it brings about when the activity is resumed at some later time, *i. e.,* in the qualitatively and quantitatively better performance of practiced, as contrasted with unpracticed work.

It is with this persisting practice-result that school instruction has primarily to do.

Both these forms of practice-result, moreover, are the more evident the less practiced we still are in the activity, and the less evident the more frequently we have had an opportunity to exercise the activity (Cf. in this connection, Offner, *Das Gedächtnis,* 50 ff.). And finally, there comes a time when, even if fatigue is not present, there is no further practice result, neither of concurrent nor of persisting practice: this is the moment of maximal practice.

Habituation. Hand in hand with practice goes habituation. We cease to be struck with the novelty

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or peculiar character of the work. Many a bit of work that was distasteful at the outset loses its character of unpleasantness. Ideas foreign to the task become fewer and fewer, and we are able to give ourselves over to our activity with more and more attention. But maximal habituation is soon attained.

This shows us how we can exclude, at least for experimental purposes, these effects of practice and habituation, and so remove an obstacle to the determination of fatigue. In order to observe fatigue, we can evidently select just those mental activities in which we have become so trained by extended practice that no further increase of efficiency can be had during the work—such activities, for example, as counting or very simple computation, particularly if they have been brought up to the highest attainable degree of efficiency by a period of special practice. Baade (39, 107), however, maintains that complete elimination of the influence of practice is at present impossible, and that its exact computation is scarcely more to be expected. But we can partly avoid the practice-error by constant change of the subjects, so that at least no permanent practice-gain shall develop in any of them.

Warming-up (*Anlauf*). Once again, in tasks such as we are considering, the work done is by no means at its maximum at the very beginning, but reaches its best output both qualitatively and quantitatively some time—usually, of course, a short time—after the start. This is a matter of every-day observation. We make use of such expressions as: "We haven't got into the game yet;" "We must get into the spirit of the work;" "We must get warmed up first;" "The

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machine must settle down to work." This stage we may term 'warming-up.' It is a stage that is passed quickly by some persons, but takes more time for others. Children, it may be added, take longer than adults to settle down to a new piece of work (Meumann, II, 5 f.). The stage is particularly long if we have been previously occupied in some other form of interesting work. But when we are once properly warmed up, when we once have ourselves in trim, then we 'turn out' results with ease—then is the time when we are doing our best work.

Swing or fitness for work. Henceforth the work takes full possession of us. We are completely 'held' by it, or we find ourselves in a condition of full 'swing' (*Anregung*), as E. Amberg (*Psychol. Arbeiten,* I, 373 ff.), Kraepelin and his school term this mental condition, or in a condition of complete 'fitness for work' (*Arbeitsbereitschaft*), as Meumann in particular prefers to call it. It appears now that, as in the case of fatigue, so here in the case of swing, we must distinguish between a general and a special form of the condition. Anyone knows that a short walk in the morning puts us into the mood for work, into a readiness for any kind of work, more quickly than if we betook ourselves directly from the breakfast table to the work. Thus, Axel Key found nothing but good results for his pupils when they walked one to two kilometers [half a mile to a mile] to school.* I have noted in my own case that, after teaching from 8 till 9, I feel much more disposed to

*However, walking to school from a longer distance or a long trip by rail is fatiguing, and produces a noticeable effect upon mental efficiency, as Wagner has clearly shown by esthesiometric tests.

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enter upon an activity of quite another character than if I had spent this hour at home in the ordinary lazy way. Hence, the strenuous mental activity demanded for the teaching, like the activity of the walk, brings about a disposition, a fitness, for every kind of activity—brings one generally into swing.

If, thereafter, we settle down at some particular new activity and get well into the work, there develops along with, and on account of, our activity a *special swing* for this particular activity. It is this condition that Kraepelin and other investigators have in mind when they speak of swing and loss of swing. General fitness is a condition that is terminated only by fairly long intervals of rest, for instance, by a long noon-recess, by an afternoon nap, and particularly by a night's sleep; special fitness, however, is naturally terminated by a change of work, or even by brief pauses. If, for example, the work be interrupted by so short a time as 5 or 10 minutes only, our special fitness suffers at once from the interruption, and, of course, the effect is the greater the longer the interruption. It hardly needs to be said that this deleterious effect is much more noticeable if the pause is not a rest-pause, but occupied in some other form of mental work. Hence, even in the case of tasks in which we are maximally practiced, and in which, therefore, there is no question of a loss of a practice-effect for the activity with which we are working—*e. g.*, very simple problems in adding—even in such a case, the introduction of a pause that we might expect to bring about an improvement in our performance (because it indicates recuperation and some reduction of the effect of

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fatigue) is more apt to have the contrary effect. That is, when we first resume the activity in question, our performance is not infrequently worse. Of course, if there is no considerable degree of fatigue present, this lessened efficiency does not last very long. We shall come back again to this matter of the loss of swing when we discuss the problem of pauses.

Spurt. Now, it is by no means always the case that, in shifting from one task to another, our initial performance with the new task is by loss of swing inferior to our performance in the work we had just left. Often, on the contrary, the new work starts off considerably better, even though the previous work had left us quite fatigued, as in general we often note that the very first stages of any work yield strikingly good results. Here, then, we come upon yet another new factor. The explanation of this outcome, which differs, as is evident, from what we have described heretofore, is to be sought in the effect of novelty. This factor, it is to be noted, has an inhibitory effect upon many persons, but affects others, on the contrary, as a spur and stimulant, making an especially strong appeal to their attention—the stimulus of novelty is a matter of common knowledge—and bringing about the release of an exceptional amount of psychophysical energy. Following Kraepelin and his school, we speak of such a release of an exceptional amount of energy as a 'spurt' (*Antrieb*), terming it an '*initial spurt*' if it develops at the beginning of the work, or a '*spurt of change*' if at the beginning of some new and different form of work.

As, in this instance, the spurt springs from the

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stimulus of novelty, so it disappears as soon as this stimulus ceases—a condition of affairs that ordinarily comes to pass in a short time and with special and noticeable quickness if we have been fatigued by the previous work. Accordingly, a drop in the curve of performance can be plainly made out, even quite soon after the beginning of an activity—at a time when fatigue is still out of the question. This drop, it is true, lasts but a very short time. Then the curve rises again, at first quickly, until the condition of swing is fully developed, and afterwards more slowly, in consequence of the practice-effect. After a certain time, which, of course, varies with the kind and duration of the work, with individual capacity, and with the prevailing mood, the performance falls off, both in quality and quantity, if fatigue gradually exerts its baneful influence, and if the favorable effect of practice is nullified. But this is by no means always the case; much oftener the course of work is otherwise. We can become more and more absorbed in our work, particularly if it be not monotonous; our interest comes back again, as we say—or, what amounts to the same thing in this instance, our attention, our expenditure of energy—and hence our achievements recover their former level. In this manner, the effect of fatigue may be compensated for a time.

However, it is possible that quite the contrary phenomenon may occur. It may happen that the work, having now lost the stimulus of novelty, may at once become tedious; that interest, or, more exactly, attention, may quite disappear, so that finally we work reluctantly. In this event, our performance, which already suffers somewhat from fatigue, nat-

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urally falls off considerably, particularly in quality. And the reduction in efficiency is much greater than if fatigue alone were operative. But if, perchance, we recover ourselves in consequence of a some encouraging word, or a rebuke or some similar influence, then our performance once more shows a gain in quantity, and even more in quality. Soon, however, fatigue again asserts its sway, and this shift of efficiency may be repeated several times, until at last fatigue takes full possession of us, and the quality and scope of our work is reduced to a minimum. Except that, if we note that we are nearing the end of our work, this circumstance often operates as yet another and final stimulating and encouraging factor. This phenomenon is known as the 'terminal spurt' (*Schlussantrieb*), and its effect is to improve our performance, just as horses step out better when they know that they are returning to their stable. If, on the other hand, we plan, so to speak, to work without stopping, *i. e.,* with a firm resolution not to desist, but spur ourselves on and ever force ourselves to fresh exertion, then there comes a time when our ability to work is completely exhausted; we collapse utterly, and hardly ever without doing some grave injury to our health.

It is evident that it is the *will,* in different forms and degrees, manifested as rising and falling attention or interest, as indifference and recovery—whether it springs from newly-awakened sense of duty or from the sight of the approaching and long-wished-for end, or from fear of not being ready—it is the will that in these cases is affecting the course of the work, and that is, with more or less success, counteracting the

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effect of fatigue. What is thus demonstrated within the narrow bounds of experimental investigation is, moreover, a phenomenon with which we are all well acquainted.

The traveler who has reached the top of a mountain in an exhausted condition, and who has hardly a wish but for rest, forgets his weariness all in a moment if he meets some of his best friends, or if he spies some rare and long-sought plant. Or perhaps he finds that he has taken the wrong road. The approach of night, the loneliness of a totally unknown region, the fear of meeting with some accident, may so excite him that he feels no trace of weariness, that he seems to be filled anew with a vigor and an elasticity that astonish him. He hurries on with marvelous speed and endurance until he finally thinks he has found the right road. Then, indeed, weariness sweeps over him with twofold intensity, because his fear no longer spurs him on.

The will, it would appear, then, puts at our disposal extra mental power. Not that it creates it, simply that it releases an already existing capital, that it opens the storehouse once more and takes out what the organism needs for the work of the moment.

But this process reduces the supply of energy, for it is not the will that furnishes the energy, but the substances taken up and worked over by the organism. This is shown directly by the proportionately greater reduction of performance and the proportionately greater need of nutrition and rest that follow the expenditure of energy necessitated by such conditions. As Schuyten has been wise enough to see, this powerful influence exerted upon perform-

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ance by the manifold forms of skill has not had proper recognition in the majority of experimental tests of fatigue (Kraepelin's work excepted).

Naturally, it must not be forgotten, to make brief reference to the matter, that, when longer tasks are undertaken, certain *internal physiological processes,* such as nourishment, digestion, need of food, affect efficiency, and that *variations in external conditions,* especially of temperature, likewise leave some trace upon the mental condition. But the most important disturbing factor, aside from loss of attention due to intruding ideas and distracting stimuli, is, of course, fatigue.

Independent fluctuations of psychophysical energy. There remains yet one thing to which we may make allusion, tentatively. R. Schulze (*Prakt. Schulmann,* XLIV, 351, cited by Burgerstein, 594) and, independently of him, Teljatnik (Burgerstein, 594 ff.) have been led by their observations to consider the possibility that our diurnal mental efficiency is subject further to rhythmic fluctuations that occur regardless of whether we work or rest, and that do not coincide with the divisions of our work that are determined by pauses for the taking of food and its digestion. Then too, W. Stern (120), and after him, Lay (417) proved what had long been assumed as true, that there is a movement of energy between two maxima that are separated by a minimum at noon and in the early afternoon. But since this depression of mental efficiency is plainly conditioned by the midday meal, it is not an independent and special factor. Schulze and Teljatnik, however, have reference to a phenomenon which appears inde-

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pendently, and which if it be confirmed by subsequent investigations, would add another new factor to the already sufficiently large number of them.

What course a bit of work actually takes, *i. e.*, what variations in efficiency actually appear in its course, which factors are most in evidence, and which most determine the form of the curve of work—all this depends on the character of the work, on the peculiarities of its subject-matter, on the manner of its execution and likewise on the individuality of the worker, on his general disposition and upon the changing external conditions. To isolate these several factors, to bring each one of them into play by itself while the others are completely suppressed, is something that is at present quite impossible of accomplishment. It is, however, feasible, theoretically, to isolate these factors in the large and to study their effects one by one.

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THE LAWS OF FATIGUE

The laws of fatigue, particularly, can be laid down, at least in a broad and general way, thanks to every-day observation and to those experimental investigations of the last decade to which we have already given attention.

The phases of fatigue. These observations have shown that fatigue passes through different stages or phases of development. A piece of work that has at first shown improvement in quality and quantity, gradually undergoes a change that we must ascribe to fatigue. The fatigue may have been really present for some time before—though it is questionable whether we should assume that it began at the moment that the work began (Cf. Claparède's discussion, 241 ff.)—but we notice it now for the first time. This is the first stage of fatigue. During it, the speed of work, it is to be noted, continues to increase; we accomplish more, *e. g.,* more computations or more counting, in each unit of time; but the quality deteriorates; more mistakes are made. In the second stage, the quantity of work done in a given unit of time also decreases. In the third stage, with some persons the work becomes slower and slower and finally is given up entirely; with other persons there is developed a considerable excitement. Féré calls this condition fatigue-intoxication. We again do more work, but the work is hurried and irregular;

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our pulse is rapid and weak; our movements are uncertain; our sensitivity to pain is augmented (Vannod), as is the sensitivity of the sense-organs. Meumann (II, 121), for instance, has shown that sensitivity for noises is increased. And finally, this stage is terminated, as we should expect, by exhaustion and breakdown.

Types of fatigue or types of work. This description applies to the ideal form of the development of fatigue in the case of long-continued work. But the variations in efficiency are not always as simple as this, even in work of a constant character, still less so in the multiform work of the schoolroom.

In this connection we may distinguish *four types* of work-curve. The simplest or falling type is that in which the application of the test-work reveals a steady decline in efficiency and a steady rise in the number of errors. Exactly opposite to this is the rising type in which the test-work reveals a progressive diminution in the number of errors, which are fewest in the last hours of the forenoon. A variation of the first or falling type is the 'convex' type, *i. e.*, one in which the curve rises a little at first (decrease in errors) and then shows an unbroken drop (constant increase in errors). Finally, the fourth or 'concave' type of curve may be considered as a variant of the second or rising type; in it, efficiency falls at first, then continues to rise to the end of the work, *i. e.*, the errors increase at first, and then steadily decrease (Cf. Blazek, also Kemsies, *Arbeitshyg.* 17 and *Arbeitstypen*). It is possible to regard these peculiarities in the general shape of the work-curve as due simply to individual differences in type of fa-

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tigue; in that case, the curves would really be curves of fatigue. Or we may regard them as caused by individual differences in manner of working—differences in the degree to which work incites or interests—and these differences would then be thought of as added to the effect of fatigue. In that case we have a more complicated work-curve, in which the decisive element is the individually different pure curve of work. This would be the case with the rising and the concave type of curve, whereas with the falling and convex curves fatigue would be the primary factor.

It is, of course, to be remembered that these types, as we have described them, are valid only for the forenoon work of the school. What kinds of types would be discovered if we took into consideration the work of a whole day is yet to be ascertained.

Fatiguability is, therefore, a thing that shows marked differences in different persons, even in healthy persons of the same age. It is worth while calling attention to Kraepelin's proposal (*Arch. f. d. ges. Psych.*, I) that, when there is a system of sections or parallel classes, the pupils should be divided, on occasion and by way of experiment, on the basis of their fatiguability, in order to render possible treatment suited to their special type. M. Brahn has argued in the same vein. Susceptibility to fatigue, as is well known, is greater in those who are ill, particularly in those who suffer from traumatic neuroses. With them the fatigue is considerably greater than that experienced by the most easily fatigued well persons, as W. Specht (*Arch. f. d. ges. Psych.*, III) has demonstrated by the use of the method of

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continuous adding. By this experiment, Specht, and later on Bonoff, showed how we might detect simulation.

Age. Age is an important conditioning factor of fatigue. Every father who has taken his youngest out for a stroll knows well enough that little children tire out extraordinarily quickly. Of course, it is quite out of the question to carry out any exact determination of mental fatigue with them, because after a very short time they simply won't do anything more, and, according to all appearances, before they are particularly fatigued. Older children, like the six-year olds in our school, give plain evidence of fatigue after an hour, indeed, often after half an hour of school work that includes both bodily and mental tasks. These signs of fatigue appear all the sooner if the children have not previously been used to continuous activity. It is not surprising that school hygienists (Burgerstein, Adsersen, Hertel) have been able to discover a rise in the death-rate during the first year of school life. And this fact gives good warrant for the plan of G. Kerschensteiner, director of the Munich *Volksschule,* who softens the transition to the more severe exactions of the school by a freer method of instruction which leads over gradually from the liberty of the nursery to the strict discipline of the school. However, efficiency increases rapidly with age; most pupils of 14 and 15 and over show little trace of fatigue, even after three hours of school work. Of course, it is to be borne in mind that these pupils also help themselves out by relaxing their attention, and that class instruction gives more chance for this than does indi-

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vidual instruction. During the period of the best mental and physical efficiency, namely from 20 to 30, or perhaps to 40, fatiguability is naturally relatively the least of any time of life. Thereafter it slowly increases again.

It would be a mistake to suppose that this decrease of susceptibility to fatigue, or this increase of efficiency, keeps pace uniformly with increase of age. Gilbert found by the use of the tapping test, which, to be sure, is not especially accurate, that the increase of efficiency with age is interrupted by periods of special fatiguability, more specifically at 8, 13-14 and 16 years—the years, then, of more rapid physical growth (in Claperède, 208 f.).

Puberty. Mental growth, like bodily growth, is especially influenced by puberty, and much more so in girls than in boys. During this period, fatiguability, to speak of that alone, is, as a rule, distinctly increased. The school should then reduce its scholastic requirements.* But, in our German *Gymnasia,* the work of the *Quinta,* which, as everyone knows, makes unusual exactions upon the pupils, falls in the beginning of this period. Intelligent schoolmen, like Richter (*Lehrproben,* XV, 29) have for some time called attention to this evil. Since pubertal development, on the average, sets in with girls at the 13th year, but with boys only at the 15th year, it will not do to educate the two sexes together during the 12th to the 17th years. For, from 12 to 15, the require-

*Höfler (29 f., 39, 60 f., 176 ff.) has shown us how this can be done in the case of mathematics by limiting (rather than omitting) certain definition and demonstration work as given in Euclidian geometry, and how this more hasty treatment of the subject may be carried out without doing any lasting damage by lack of thoroughness.

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ments would be too high for the girls, if the average efficiency of boys of this age were taken as the standard; while from 15 to 17, they would perhaps be too high for the boys, if they were based upon the average efficiency of the girls; or else the requirements would have to be reduced, at first in the interest of the girls, in which case the boys would not be adequately stimulated; later on in the interest of the boys, in which case, again, the efficiency of the girls would not be turned completely to account. This is an argument advanced by Burgerstein (524 ff.) against coeducation in the German middle schools, and it is worthy of serious consideration. For the rest, the relations between sex and fatiguability are still quite as uncertain as those between intelligence and fatiguability. The greater susceptibility to fatigue of younger children is to be met by shorter lesson-periods, fewer hours of study and more frequent pauses, particularly in the primary grades.

Length of lesson-periods. In dealing with the matter of the length of lesson-periods we may as well see clearly at the start that human nature gives us no absolute warrant whatsoever for making a lesson-period exactly an hour, exactly 60 minutes. The fact that this is the most usual length [in Germany] is due to the simple fact that the clock is divided into 12 sections; in other words, we use hours in school just because we have got used to dividing up our day into twice twelve parts. And we divide our day by twelves for the same reason that we buy our collars, our handkerchiefs, and our candles by the dozen rather than by tens, just because of a preference for

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the number twelve that even the ancient Babylonians were conscious of. This preference, or special fondness, for the number twelve is to be traced to the astronomical fact that the moon encircles the earth twelve times in one year. To take such a purely extraneously determined custom, however ancient it may be, as a basis for the division of work, and on the basis of it to make every portion of work the same for persons of every age, for every kind of material, for every method of procedure, and for every time of the day, as our school programs, taken as a whole, have done down to the most recent times, is perfectly absurd. The only rational time at which to stop work and to indulge in a restorative pause is the time at which the worker feels that he is getting tired, or at which, if he does not notice his fatigue himself, he nevertheless displays easily recognizable signs of fatigue, *e. g.*, in addition to the poorer quality of his work (which is of special importance in experimental investigation), particularly signs of uneasiness, decrease of attention, and a tendency to dawdle—symptoms which may even be seen, not only in ordinarily attentive and conscientious children, but also in adults These and other like symptoms should obviously not be regarded, as is all too often the case, as invariably punishable offenses, but as signals of fatigue, as signs that the work ought now to be stopped and opportunity given for rest.* To decide when the pupil has reached this stage in his work is precisely the teacher's problem. To do it he needs psychological understanding.

*F. Galton, *Jour. Anthrop. Inst. and Revue scient.*, XVII (1889); also A. M. Boubier, *Arch. de Psych.*, I (1902).

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Moreover, the teacher can make allowance, without introducing any pause, within any given part of the school program, for the fatigue (which, as we know, does not exactly conform to the program divisions); he can check the too rapid development of fatigue by changing his manner of treating the subject-matter of the lesson, by making a transition to some other phase of the same subject-matter, and by other similar variations. In this way he can fit the length of the lesson-period specified in the school program to the individual needs of his classes.

On the other hand, the length of the lesson-period in general cannot, of course, so far as the public schools are concerned, be cut to fit the special needs of a single class, but must be arranged to suit the average efficiency of all the classes of the same grade. It would need only a few well distributed experimental tests to secure the information necessary for this purpose. It is only in the last 15 years that we have brought about what the investigations of the school hygienists have been demanding for the past 40 years, that here and there authorities have shaken themselves free from the bonds of the customary distribution of time into hours and have granted to the younger pupils, or at least to the more easily fatigued elementary grades, the shorter lesson-periods which the maturer pupils of the higher schools have long enjoyed. For feeble-minded children, indeed, a half-hour ought to be regarded as long enough for a period (Heller).

Thus, in the middle schools of Norway (*Gymnasia* and the like) the lesson-period, since 1896, has been limited to 45 minutes, and in Berlin, since 1898, the

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period has been set at 30 minutes, at least for the lowest grades of the *Volksschule*. Like improvements have been tried in other cities (Cf. Burgerstein, 543 ff.). It is to be recommended, however, that, for the upper grades of the *Volksschule,* and still more for the more exacting *Mittelschule,* the lesson-period be increased to 45-50 minutes (the so-called 'short-hour'), and that a pause of increasing length be introduced after every period. At Karlsruhe, since 1894, the limitation of the class-period to 50 minutes in the *Oberrealschule* and the *Realgymnasium* has yielded good results and has made it possible to have a continuous five-hour session (Treutlein). And R. Keller (*Intern. Archiv.*, II, 297 ff.), according to the unanimous verdict of his school-board (which was at first distrustful of the idea), has, by the use of a 40-minute period, attained excellent results, especially in the lower classes, in the *Realgymnasium* and the trade school at Winterthur. Nevertheless, it will sometimes be found worth while, for the sake of school work, to extend the lesson over the hour period. To this point we shall return later on. Reducing everything to rule, however desirable it may be, is more likely to work injury in educational work than it is in any other field. W. Hellpach, of Karlsruhe, proposes as a regular weekly schedule the introduction, in addition to the ordinary short-hours of 45 minutes, of six 'long-hours' of 80 minutes each—this, however, only for the upper grades whose members have passed the period of puberty, and only for review work. But even this type of work, if the pupils co-operate actively, makes intensive demands upon time, as may be noted in every bit

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of assigned work or class work that lasts more than an hour. To use such long hours as a regular schedule would be a debatable proposition.

Number of periods per day and per week. A new question arises when we discuss the total number of class-exercises per day. Instinctively, and quite properly, most schools are inclined to limit the formal program to three forenoon and two afternoon periods [hours], and to allow a maximum of four, or at most five periods, only in the case of exclusively forenoon sessions. At the Hamburg *Gymnasium,* however, as many as six periods have, for some time, been combined into a single 'morning' session—from 9 to 3 in the winter and from 8 to 2 in the summer—though, of course, in conjunction with suitable rest-pauses (Treutlein, 20). And the same arrangement is often followed in Sweden (Burgerstein, *Handbuch,* 590). A similar experiment (six periods of 45 minutes each) was made at Elberfeld in 1899, but after several years' trial, they returned to a five-period schedule, because the higher school authorities, who could not convince themselves of the advantage of the plan, forbade it, and with right. Even the fifth period, despite longer pauses, is, at least with industrious pupils, of little value. When the pupils co-operate actively, four successive hours of required work constitute the maximum. Anyone who, in his student days, has attended lectures for four hours in succession will remember that he was unable to take in anything more after the fourth lecture—and here all the periods were 'short hours' and he himself was a grown man. Kemsies' observations are in accord with these statements, and he proposes (*Arbeitshygiene,* 64) four

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hours for younger and five for maturer pupils as the maximum per day. G. Heberich and K. Schmid-Monnard (292 ff.) demand that the *maximal number of hours per week* shall be 24 regular hours. This figure is least exceeded by the humanistic *Gymnasia* of Bavaria, with their 27 periods in the highest classes, as compared with 31 in the *Realgymnasium*. It is another question how much time should be permitted for optional work. It can hardly be denied that very many pupils do too much for their good, and that many teachers do not restrain them from it, as if this elective work made no demands on nervous energy. For this type of work, too, a maximum time should be allotted; three periods a week in science, three or four in music, two or three for drawing and stenography should be the maximum for elective hours. If the home throws a burden of added hours on the pupil. then it must itself take the responsibility for it. But it would, however, be well for the school to warn the parents over and over again of the dangers of such overburdening of their children and to show them very clearly what their responsibility is in this matter, for they are seldom sufficiently well aware of it (see also Dörnberger, *Med. Prax.*, 13).

Days of the week. Another debated question is: What days of the week are most favorable for mental work? School authorities are apt, as a rule, to think little of the days, or at least of the first half of the days, that follow Sundays and holidays, and it is, indeed, out of kindly consideration of this circumstance that in many places it is forbidden to assign written tests or problems on these days. Kemsies (*Arbeitshygiene*) reached, however, somewhat different re-

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sults, for he found the best days of the week to be the first two after a holiday, *i. e.*, Monday and Tuesday, though to be sure, Monday was good only in the third and fourth periods. It takes, then, somewhat longer than usual to get back the general swing that has been lost during the holiday. This difference of opinion can be settled only by further and more extensive investigations. In any case, efficiency falls off plainly from Wednesday on. And most school programs take cognizance of this fact by inserting a half-holiday on Wednesday, though this, to be sure, does not prevent the evasion of the purpose of this half-holiday in some places by the introduction of optional instruction. In France and in parts of Austria, Thursday is left entirely free (in the celebrated Schulpforta *Gymnasium*, all of Wednesday); here the expectation is that the day will be devoted to elective work, not be spent in doing nothing.

Pauses in school work. And this has brought us naturally to discuss the problem of pauses. Let us first consider the *short pauses*. What for purposes of instruction is lost by these pauses in time is made up in quality. This is shown clearly by the experimental tests with exercises in dictation and computation that J. Friedrich (*Zeits.* XIII), at Külpe's instigation, applied to the pupils of the fourth class of a Würzburg *Volksschule*. As has been known for a long time, the pause has a recuperative effect—though naturally only when it is actually used for rest, for non-compulsory activity (especially in fresh air), or for taking a moderate amount of nourishment, not when it is taken up with studying or with gymnastic exercises or strenuous games, as is so often the case

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in England (Abelson, 484). That this rest-pause is the more beneficial and the more recuperative, the longer it lasts, and that its effect is the more noticeable, the longer the previous work had been,* is no less certain than that the rest-pause must be made so much the longer, the more fatiguing had been the previous work, the more the psychophysical energy had been drawn upon. From this it follows that—if we take no account of differences in difficulty of the various subjects in the curriculum—the first pause should be the shortest, and that the pauses should be made longer and longer in order to prevent a too rapid lowering of efficiency, *e. g.*, 15 minutes at 10 o'clock, 15 to 20 minutes at 11 o'clock, and finally, at least 20 minutes at 12 o'clock. In working with feeble-minded children, the pauses must be made still longer, since these children are much more liable to fatigue (Heller). What holds good for the way the shorter pauses are occupied, holds good also for the long ones.

That gymnastic exercises are really work, and therefore out of place in rest-pauses, will be brought out clearly later on.

The *noon intermission* is a pause of special significance. As our day is at present divided, this pause serves to secure an abundant supply of nourishment. The organism is so much concerned in the subsequent processes of digestion that it has little energy to spare for mental work. The organism demands quiet. "*Plenus venter non studet libenter*" is a well-established maxim, and if it be not heeded, the work is done less successfully and with greater effort, as

*The experimental confirmation of this and of similar observations has been supplied by G. Heŭmann (*Psychol. Arbeiten*, IV).

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Abelson (434) has clearly shown by esthesiometric tests. And so the schools have been very properly forbidden to set tasks that can be completed only by working over the noon hour. The school cannot prevent some pupils from preparing a part of their afternoon lessons and other eager pupils from running over their assigned work once more during recesses and intermissions. This undesirable kind of work during the noon hour can be entirely avoided only by giving up all informational instruction in the afternoon. Besides, the noon intermission, which, as scheduled, is already much too short, and which is frequently misused by being put to other mental work, is yet further shortened, and to a considerable extent, by external conditions. In the larger cities it is unfortunately impossible for all of the pupils, whose instruction, on account of elective work, often runs to 12 o'clock, to get to their dinner table by half-past 12 and to finish the digestion of their dinner and to regain sufficient mental freshness by 2 o'clock, when the afternoon work ordinarily begins—to say nothing of the fatigue set up by the morning's work that should be eliminated so far as possible. The indisposition for mental work that every teacher, even the youngest of us, notes after eating, and that many persons can drive away only by the use of coffee, is felt by the pupil, too, especially during periods of rapid growth and also when the weather is hot. And the ability of the school child to do mental work is fully restored at the beginning of the afternoon session only in the rarest cases (Griesbach, Vannod, Wagner, Friedrich, and Burgerstein in his *Handbuch,* 581 ff.). It is, accordingly, one of the most jus-

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tifiable demands of school hygiene that the afternoon session, if it be not done away with entirely, should begin at the very least two hours after the noon meal, *i. e.*, at 3 o'clock, and not at 2 o'clock, which would be justifiable at most only if all the pupils sat down to their dinner at 12 o'clock—a custom that is becoming less and less common in our larger cities as the years go by.*

The pause that yields most abundant recuperation is, of course, *sleep,* during which, if it be quiet and dreamless, it may be assumed, no fatigue-substances are produced at all, while assimilation far preponderates over dissimilation. Without recounting in detail the laws of sleep discovered by Römer, we may point out simply that, in general, the same laws that hold for pauses of all kinds hold also for sleep. Sleep must, accordingly, be the longer, the more strenuous has been the work that has preceded it, and the more easily fatigued the organism is. It follows that the need of sleep is the greater, the farther the person is from the stage of mental and physical maturity. Babies spend, or should spend, the greater part of the time in sleep. And Axel Key (166 ff.), the Swedish school hygienist, is right when he demands 11 hours of sleep for 7 to 9 years old children, 10 hours for 10 to 13 year old children, and as many as 9 hours for older pupils. Adult mental workers need from 7 to 8 hours. It must not be forgotten in this connection that the need of sleep is less in summer than in winter. Unfortunately, we know full well that very many school children tend to spend in sleep fewer hours

*The *Max-Gymnasium* at Munich begins afternoon instruction in summer anyway as late as 3 o'clock.

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than they should.* The blame attaches sometimes to the home, sometimes to the school, and frequently the trouble lies in external conditions, such as poverty and the like, over which neither school nor home has control (Cf. Burgerstein, 680 f.) The recuperative effect of sleep is, of course, the greater, the less the organism's activity is continued in it, the less, in other words, the sleep is disturbed—whether by outward impressions, by dreams, by the after-effects of strenuous mental work undertaken just before going to bed, or finally, by indigestible or stimulating suppers. It is, therefore, essential that pupils should not be allowed to continue their study up to the time they go to bed, but should be busied with light reading, simple music or games and the like. All the school can do in this connection is, of course, to give good advice to the parents. The school has still more interest in—but, unfortunately, has still less influence upon—the external conditions under which children get their sleep—conditions which, as Friedrich has shown for Würzburg, Bernhard for Berlin, and Ravenhill for English elementary schools, are often the worst conceivable. If a full amount of sleep is not sufficient to restore the capacity for work completely by the next morning, then the demands made on the organism by the work of the previous day were too great for its efficiency. This might occur either because the efficiency had itself been weakened (perhaps by illness or inadequate nutrition), or because excessive demands had been made upon a person of perfectly normal efficiency, *i. e.*, upon an efficiency

*Dörnberger and Grassmann (12) found, however, that pupils in the *Gymnasia* at Munich had enough sleep.

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that had not been reduced by any otherwise unfavorable circumstances. In the first instance, we have over-fatigue as a result of an abnormal and especially pathological fatiguability; in the second case, we have over-fatigue as over-burdening, *i. e.*, as a result of activity that exceeded the normal capacity. It is hard to prevent occasional over-fatigue, and we need not take that very tragically. But if it is repeated, or if it persists, and if, for weeks at a time, sleep and the other rest-pauses that interrupt the work do not completely restore the efficiency available at the beginning of the periods of work, if the periods of mental freshness become shorter and shorter, and if fatigue sets in earlier and earlier—as both teachers and pupils frequently experience after a hard year of school work, or as mental workers in general experience in the form of the well-known 'year's fatigue'—then, indeed, we have a condition that calls for serious consideration. These symptoms show that, just in these longer periods of work, the consumption of nervous energy has gone so far that the ordinary rest-pauses no longer suffice to restore it completely. Quite often, even in a case like this, a still longer pause, one of several days or weeks, especially a vacation, may bring energy back to the height at which it usually stands in the first weeks of the school year. If the restoration of the original efficiency is not brought about even then, we have undoubtedly to do with exhaustion. Schuyten (*Overlading*, etc.), unfortunately, did not apply this final and decisive test.

If this sign of over-fatigue, or exhaustion, appears in the majority of its pupils, the school must make a considerable reduction in its demands and change its

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methods. If, on the contrary, it appears in only a few pupils, the home must realize the fact that the task has become too hard for the pupil, and must permit him to repeat the grade in order to give his body and mind a chance to develop the physical efficiency and the mental maturity that is absolutely necessary. Or, if even the longer rest-pauses of the vacations do not restore his old-time vigor, there may be some disease or the after-effect of an excessive degree of exhaustion. To hold a pupil thus afflicted down to mental work is as great a crime as to load him with overwork to the same degree. Sleep, therefore, affords us a reliable criterion for the differentiation of normal fatigue from that which is induced by pathological or other unfavorable conditions or by overburdening.

There is better agreement as to the significance of sleep than as to the most advantageous length and distribution of the longer pauses in school work, *i. e., the vacations*. In southern Germany the usual arrangement calls for nine weeks of vacation in the summer, 10 days at Christmas and 16 days at Easter, with no long vacation at Pentecost, but in northern Germany there is a vacation at Pentecost, and the somewhat shorter summer vacation is divided into two parts, though, it must be admitted, not without much opposition. The Christmas and Easter vacations are here approximately as long as in southern Germany.*

Again, many observers feel sure that relatively

*Burgerstein points out that hygienic considerations other than fatigue favor a threefold division (*Die zweckmässigste Regelung d. Ferienordnung*, in *Bericht u. d. 14 Intern. Kong. f. Hygiene u. Demographie*, Berlin, 1907, Vol. II).

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short and frequent vacations are more favorable for school work than relatively longer and fewer ones. Certain it is that, during long vacations of several weeks duration, the pupils drift farther away from the spirit of school work than they do during short intermissions of only one or two weeks. Yet this is no disadvantage from the hygienic point of view. It is a good thing for pupils completely to forget their school cares and duties once in a while, and this they can scarcely do in one or two weeks. Of course, it is equally true that they forget a good deal of what they have learned as well. But systematic drill, with repetition, can re-create this lost material in the first weeks of the new term, without delaying entrance upon the new work for which the pupils are eager. However, this is a matter that has not been sufficiently tested scientifically as yet.

Even if the loss occasioned by the long vacation could not be easily recovered, nevertheless the arrangements of vacation periods already made by the school authorities and in other social and business circles would have to be considered. To make new vacation arrangements at the risk of rendering more difficult the gathering together of the whole family (a custom that leads to the arousal of a multitude of stimulating ideas in the new surroundings of country life and that affords both children and parents opportunity for a more intimate mental intercourse than the busy days of the remainder of the year) would be to administer a serious setback to the development of family life that already suffers manifold restrictions in other ways. In this matter school hygiene will have to give way somewhat to social and ethical con-

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siderations, to the hygiene of the spirit of family life, and this it can do without undue anxiety, since, so far at least, no serious hygienic disadvantages have been shown to follow the long vacation.

The shorter pauses, too, have their *disadvantages*. They break up the work, and this interruption means loss of swing, of fitness for work, or of the pupil's adjustment for the particular work on which he is engaged; and if the interruption is longer, this means the loss as well of the readiness for mental work of any kind, the loss, in other words, of what we have termed 'general swing.' The experiments of W. H. Rivers and Kraepelin (*Psych. Arbeiten,* I), of E. Lindley (*Psych. Arbeiten,* III), and of Heümann (*Psych. Arbeiten,* IV) teach us that the loss is the greater, the longer the interruption lasts and the more our attention was adapted to these objects, was accommodated for the one particular work.

It is clear that the loss of special fitness is not injurious, provided the new lesson deals with a totally different kind of material, but that it is very disadvantageous if the same lesson is continued or if the new lesson is closely related with the subject-matter of the preceding one, *i. e.,* if it is pedagogically allied to it—as, for example, if the material of a lesson in history was to be worked over for a bit of composition work in the German lesson that followed it. Since, in a case like this, the ideas that had been gained in the first lesson would have to be developed again in the next one, it is better to make the transition without any pause, as is, in fact, usually done in the case of German composition work. It is assumed, however, that lessons thus prolonged are followed by

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longer pauses for recuperation, and that they should be limited in use to the upper grades. In these upper grades, where, for the sake of pedagogic unity, a lesson must often present and work over a considerable number of ideas, the lesson-period in general must frequently be longer than in the lower grades. And the lessened susceptibility to fatigue of these maturer pupils makes such an arrangement permissible.

Naturally, the loss of general swing is another matter. To lose it works injury even when the subject-matter of the new lesson is quite different. The first five or ten minutes will always be handicapped by the very unfavorable influence of an incomplete fitness for work. The school would best be served by short pauses which would permit the general swing to be maintained, though specific fitness would be lost, and at the same time a certain amount of recuperation would take place. To select just the best length for pauses—a length such that the loss of swing and the gain in recuperation would balance one another—is, on account of the many contributory factors, a problem by itself, the solution of which still presents so many difficulties to experimental psychology that it would be safer and better for the school to choose the lesser evil, the loss of swing, so that it may at least avoid the greater evil, overburdening.

Change of work: special and general fatigue. Change of work also brings about recuperation oftentimes. If we mean by this statement that, when we resume a task that we have interrupted by some other form of activity, we then work considerably better than before the interruption—that, to speak more accurately, we enter upon the task again with a fresh

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supply of energy—then the statement, in view of the preceding discussion, is very much to be doubted. It cannot be supposed that, in our complicated psychophysical organism, an activity of appreciable intensity can run its course in any part of our complicated psychophysical organism without thereby affecting the functions of the other portions of the organism, and hence of the whole organism. And the more manifold, the more intimate the connection of the one part with the remaining parts, the more rapidly and the more extensively will the fatigue make itself evident in these parts as well.

Conversely, the less the active part be connected with the remainder of the organism, the more it is possible to limit its functioning to itself, the more slowly will the fatigue spread to the other parts, and the more possible will it be for the fatigue to take on the semblance of localized and isolated fatigue. This is shown by Urbantschitsch's observation that a continuous tuning-fork tone after a time becomes inaudible, although the striking of any other fork readily evokes its proper auditory sensation. The organ, then,—whether as a whole or in some definite part we need not try to decide—fatigues for just that one tone, but not—or more exactly, not yet—for the others. This is substantially the same thing as J. J. Müller discovered, when he proved that overtones become ineffective if they have been given intensely just beforehand. Another example of fatigue by and for a very specific activity is the negative after-image, for this—at least in terms of the Young-Helmholtz theory of color sensations—is an instance of fatigue for the color previously seen (or the light-

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waves that correspond to this color), coupled with continued sensitivity for other colors (or other light-waves).* Finally, the marked unreliability of the physiological methods of measuring fatigue, especially in the case of mild degrees of the fatigue set up by mental work, is most easily explained by the assumption that the active parts of the organism fatigue first of all, and that the organism as a whole, especially the musculature, is only gradually sympathetically affected. The same assumption, too, enables us to see how there may be a general, as well as a special fitness for work. There is, then, such a thing as *special fatigue,* which we must look upon as a consumption of the constitutive materials of the active organ—a process that in the very nature of the case is limited to the organ in question—and as a secretion of fatigue-substances that accumulate at first at the point where the work is done.

Nevertheless, there is *no isolated fatigue.* The fatigue-substances do not remain where they are secreted, but are carried forth through the whole body by the ceaseless circulation of the blood. Thus, there appears a general as well as a special fatigue. Moreover, the fact that the part of the body that is vigorously at work is continuously and extensively drawing recuperative materials from the circulation must bring it about that a lesser amount of these materials remain at the disposal of the other organs. And Mosso even believes that an organ draws upon the supplies of other organs as well, that it uses up their reserves, so to speak, *e. g.,* that the brain, during its activity, draws upon the muscles for recuperative

*Cf. L. Hermann, *Lehrbuch der Physiologie,* 2d ed., 523 f.

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substances. This is the second way in which fatigue may spread from the active organ. It follows quite clearly from this that, when one organ is intensely active, there cannot well be any storage of recuperative materials in the other organs, but that, on the contrary, these organs must also in time be exhausted. And, of course, the same thing is true if vigorous activity is discontinued in one organ, but set up in some other with equal intensity. Accordingly, change of work, or more properly, changing the organ that works, does not bring about recuperation as long as the consumption of materials continues at the same rate.

If, however, the work to which we change is considerably easier—if it is of such a kind that, to put it in the terms of our discussion, it generates a smaller amount of fatigue-substances and makes smaller demands on the available supply of material, and if the supply of material, at least by respiration, goes on unchecked—then change of work may, it must be admitted, bring about recuperation. Whether and to what extent a given piece of work is easier depends, naturally, on the kind of work that it is, and also upon the individuality of the worker, his knowledge, his native ability, his susceptibility to practice, his skill, his interests, and the like—in short, on the manner and method in which he takes his work.

But we think, too, that we can often discern a recuperative effect when we change from one form of activity to another of equal intensity. Here, however, it does not appear that we are dealing with recuperation in the strict sense of the term. The work that is resumed is not essentially better than it was before

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the interruption. Not essentially better, we must say, for the inevitable slight pauses do actually exert some slight recuperative effect, and our fresh start is affected favorably by an initial spurt, here the spurt of change, as we have termed it. Our work, however, is certainly much better than it would have been had we continued without any interruption to the same moment of time. It is, then, not really bettered, but has simply not grown any worse. Obviously, because the consumption of material in the organ in question ceased during the interruption, whereas in the second case, it would have continued uninterruptedly.

The experiments conducted by Weygandt (*Psychol. Arbeiten,* II and Kraepelin, *Uberbürdungsfrage,* 9 ff.), that are often cited as decisive against the recuperative effect of a change, do not, of course, really suffice to refute this assumption or that of the existence of partial fatigue. His experiments merely prove that if an easy piece of work interrupts a more difficult one, the result is that we do better when we resume the difficult work than we would have done if we had worked on with the difficult task for the same length of time without the interruption—a result that is perfectly intelligible for us from what we have already seen. His results do not, however, prove anything against the idea of special fatigue or anything against that of an advantageous effect arising from the change in kind of work (neither do the experiments of Schulze, in which changes were arranged between adding and copying letters), for the forms of work used for the shifts of activity (adding, memorizing of series of numbers and syllables, cancellation, the reading of texts in a foreign language, etc.)

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are too much alike. Of course, they are different sorts of operations, but they involve either the same or similar elements. Physiologically considered, they are processes that run their course very largely in the same brain regions. Different brain regions will always be brought into action in some measure, if the subject-matter of a lesson is treated in quite different ways—if, for instance, the subject is presented at first pictorially and concretely, then descriptively and more abstractly. By such a method the pupil's efficiency can be put to use more rationally. The points at dispute hinge on such questions as whether a specific region of the brain can fatigue without affecting other regions also; whether an activity that we think of as exclusively—or, since this is hardly conceivable, as predominantly—centered in a specific part of the brain, and that we must consider as being predominantly an activity of a single or of certain determinate phases of mental life, fatigues quite by itself and leaves our mind in full efficiency for such other activities as we ascribe to other regions of the brain and as are evidently other phases of mental life; whether, then, a fatigue can not only be special when it begins, but can remain special, isolated, and localized, or whether it spreads gradually over the entire psychophysical organism, or whether, finally, it induces from the very beginning an equal amount of impairment of efficiency in all parts of the organism. Our discussions have shown that *we must admit a special fatigue, but deny its isolation.* But it follows from this that change of work brings about for the regions of the brain freed from work a cessation in the consumption of the materials

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of which the nerve cells are built up, so that, when the former activity is resumed, this fact, taken together with the spurt of change, results in better performances than before the interruption of the activity, and in this way there seems to be a recuperation.

And the fact that in the new work, *i. e.*, in what might be called the 'change-work,' more is accomplished than at the end of the previous work, despite the general reduction of efficiency to be expected from the distribution of the fatigue-substances, is intelligible. On the one hand, the stimulus of novelty reawakens interest and incites us to a greater expenditure of energy (the effect of mood). On the other hand, the parts of the organism that are set into activity by the new work have not yet been concerned in work; their store of energy has not yet been assailed.

It is, of course, presupposed that the previous work had fatigued the organism only moderately, and that the new work is essentially different from that that had preceded it.* On this account, the form of change that most effectually slows the progress of fatigue, though it does not, of course, entirely check it, is the change from mental and bodily work. All in all, the view frequently held by educators (*e. g.*, Richter, *Lehrproben*, XLV, 14) that change means recuperation appears to be but the psychologically and physiologically unjustifiable interpretation of observations that of themselves are not incorrect.

Social activities. What we have said about the ef-

*Special (partial) and general fatigue are distinguished also by Mosso (244), Kraepelin (*Uberbürdungsfrage*, 16) and, apparently, by Claparède (236, but see 218 ff. and 268 f.), only that these writers lay more emphasis upon the general effect, while Teljatnik (in Burgerstein, 467) emphasizes rather the partial fatigue effect.

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fect of change of work holds true in the main for the effect of social life. If the pupil's social activities make only slight demands on his mental life, if they call forth only a moderate degree of interest, if they serve to divert and amuse rather than to excite, then they are good things to conclude the day's work with, particularly because they prevent the carrying over (perseveration) of the thoughts and worries of the day.* But if these social activities fetter our attention and render us 'all stirred up,' then they are really another kind of work—quite apart from cutting short our time for sleep—and then we must ask ourselves seriously the question whether the satisfaction that we hope to gain from them is enough to compensate for the loss of mental efficiency on the following day.

The home will see to it that school children at least are kept from strenuous social activities, if it is all desirous that their studying shall not be interfered with.

Gymnastics. The same general principles apply to every sort of bodily movement, and especially to gymnastics and active games. When these are pursued vigorously, they are distinctly fatiguing, and are, in any event, not recuperative, as used to be generally believed. Anybody who has done intensive gymnastic work or played tennis or enjoyed sport on the ice knows how little inclined he was afterward for mental work. Griesbach, Wagner and Vannod found a considerable reduction in the sensitivity of the skin under such conditions. And other investigators have

*On perseveration, see Offner, *Das Gedächtnis*, 23 f. and elsewhere.

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in other ways proved that gymnastics exert a strong fatigue-effect; in fact, all who have used scientific methods of measurement have come to striking agreement on this point (Cf. Burgerstein, 570 ff.).* However, this kind of fatigue-effect, when of moderate degree, has the merit that one speedily recovers from it, so that, even after an hour's rest, especially if nourishment be taken during that time, one feels again prepared for mental work and one may accomplish very good results in it (Cf. Abelson, 414, 486). The reason for this is that there are operative here other favorable factors which can soon cancel the fatigue-effect. The vigorous exercise, especially when taken in fresh air, the augmented metabolism and the consequent augmented supply of the materials that build up the body, particularly the augmented supply of oxygen through the quickening and deepening of respiration and of nutritive material through the quickening of appetite, the hastening of the elimination or the oxidization of the fatigue-products, all these are factors that condition a rapid renewal of the stock of psychophysical energy used up by the strenuous bodily activity. So that gymnastics may, after all, possess indirectly an unquestioned recuperative value, not merely an apparent one, as Gaupp (118) thinks. When interpreted in this way, there is justification for the general opinion of the value of exercise—an opinion in which no distinction is made between the direct and the indirect effect of exercise. If, however, the subsidiary effects which

*See also the results of Smedley at Chicago, in Rept. Dept. Child-Study and Pedagogic Investigation (46th An. Rept. Brd. Educ., Chicago), 1899-1900.—*Translator.*

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bring about this rapid compensation of the fatigue were to be restricted, then the fatigue-effect of bodily exercise would assume large proportions. Thus, gymnastics in closed or poorly ventilated rooms have very little value. Since these beneficial secondary factors are not immediately effective, it is easy to understand why we are not in a position to do intensive mental work directly after active physical exercise, but only after a rest of three-quarters of an hour or an hour. In cases, however, like that cited by Holmes (Ped. Seminary, III), who found, by means of the addition test and a test of bisection of lines, that a moderate walk and a brief four-minute calisthenic exercise in the school room were directly stimulating to mental work, and like that cited by Dornblüth, who noted a similar result after a gymnastic lesson that did not make great demand on energy or attention—in these cases, we must conclude that the consumption of energy by the physical activity is more than compensated by those indirect effects that augment the supply of energy. Moreover, in the case of walking, rhythm is a factor that is not to be underestimated, since it exerts a favorable influence upon our mood (Cf. Offner, *Das Gedächtnis*, 84, 86, 190). That a short walk might have a stimulating effect we showed previously, in our discussion of swing. There are, then, considerable differences in the effect on mental efficiency of different kinds and degrees of bodily movement, and variations in the bodily constitution of the individual introduce yet other differences.

Science can only lay down general principles. It will be the business of the home and of the school to

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determine for particular children, or groups of children, by dint of careful observation, in what way, to what degree, and at what time physical activity is a healthy counteractivity for mental work: as it will be also their business to determine how gymnastics, that obviously serve not only hygienic, but also pedagogical purposes (training in discipline, order, vigor and physical development), shall be given due place along with the studies of the school, and how neither physical nor mental training shall suffer from the other, but shall be of mutual advantage. The working out of this problem is the art of pedagogic diplomacy. Theory can supply only certain guiding principles. the most important of which are: Physical activity is also fatiguing work. It cannot, therefore, afford recuperation after mental work, but itself demands a period of rest. It is, however, accompanied by secondary results that are extremely helpful for recuperation after mental work. These secondary results are best realized when there is no activity of any kind directly after the physical activity; for this reason, it is well to have the exercise come at the end of the formal school instruction, particularly because it then satisfies the desire for movement that comes from sitting still for a long time. If the exercise be carried out with less intensity, it has a stimulating effect, and then, but only then, it can be taken between, or even before, the period of formal instruction.

Fatigue-coefficient of the studies. We see, then, that gymnastics and similar physical activities have a special relation to fatigue. But, in the same way, every discipline, every subject-matter, has its own

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peculiar way of setting the mind into action, and hence the fatigue-effect is different for each of them. One of the special chapters in the investigation of fatigue—Griesbach is, in fact, the first to state the problem—has to do with determining which subject fatigues the most and in what direction the most; in other words, with determining, at least quantitatively, the specific degree of the fatigue-effect of each study (other conditions being equal). This we may term the fatigue-coefficient. It affects the outcome of mental work as the friction of machines, indicated by their coefficient of friction, lessens their mechanical efficiency. By the use of this fatigue-coefficient, there might be made out a fatigue-scale of the several school subjects that could apply either to the ability and disposition of the single pupil or to the average capacity of an entire class, and to a given age or stage of development as well. The experience of the schoolroom has taught us for a long time that certain studies strain and fatigue some more than others of the pupils, and that there are certain lessons and certain subjects that make greater demands than others upon at least the average of the class. The results obtained by Griesbach with the esthesiometer accord pretty well with this schoolroom experience, as they show that mathematics and memorization-exercises are very fatiguing, much more so than geography or drawing. Similar, though not identical results have been obtained by Wagner, Sakaki and Blazek, with the same method, and by Kemsies with the ergograph (*Deutsch. Med. Wochenschrift*, 1896). Both Vannod and Vaschide showed by the use of the esthesiometer that mathematics and ancient languages are more

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fatiguing than geography and French (here the mother tongue). But it is interesting to note that Vannod found drawing to be strongly fatiguing, also. Quite in accord, again, with schoolroom experience is Ritter's observation that exercises in sight translation are more exacting than the reading of the authors. There is no reason to be surprised that these experimental results do not show more exact agreement when we consider the inequality of the conduct of class instruction and of the requirements of schools of different, and even of those of the same type, and when we remember, further, that the measurements were not all taken by the same method and that the subjects in question were conducted at different lesson-periods (before or after a pause, before noon or after noon, at the beginning and at the end of the school day), and that this discrepancy has not been allowed for. There are also involved here certain other factors that we shall discuss later.

Afternoon instruction. The specific fatigue-effect of afternoon instruction is still undetermined. Sakaki, Vaschide and Vannod, on the basis of their esthesiometric tests, made out that afternoon instruction fatigues much more than forenoon instruction. Similarly, Schuyten found (*Voor- en Nam*) that in afternoon sessions more errors were made in copying and poorer results were exhibited in learning two-place numbers. But it is not certain how much the physiological factor, digestion, may have affected this result. We may assume, on the other hand, that the taking in of nourishment brings with it a restoration of the supply of energy. The ergograph, and likewise the dynamometer (Schuyten), shows that

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bodily strength is increased thereby. Ritter concluded from his use of the word-learning method that his gymnasial pupils at Ellwangen were somewhat, though not much more fatigued by a two to three-hour afternoon session than by a four-hour morning session. It depends entirely on the length and use of the noon intermission.

In view of the fact that the time from 4 or 5 o'clock to 8 o'clock or later is the best part of the day for very many mental workers, and that of 64 mathematicians who replied to a questionary, 24 asserted that the evening was their best time for work, while seven rated morning and evening as equally good (Claparède, in *L'enseignement math.*, 1908, pp. 216 f.), we certainly cannot urge any theoretical objections against instruction that begins late in the afternoon, provided care be taken that the process of digestion is entirely finished. Or, if we may disregard entirely the disputed question of one-session or two-session plan (a question complicated by other and quite different issues, *e. g.*, possibility of adequate physical activity, distance of the home from the school, time-consuming and wearying trips on rail and street cars, and in winter, too, the problem of illumination,* and, furthermore, the oversight of pupils that have no afternoon instruction and the question of meal-hours as they are affected by parental occupation and other local customs)—if we disregard this question, we should like to put the matter quite generally by saying: 'Readiness for mental work is renewed in the second part of the day at two to three hours after

*Consult the judicious treatment of the question in Burgerstein, 578 ff., and in Treutlein's *Progr. d. Realgymn.*, Karlsruhe, 1906.

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eating the noon meal. This second work-period is, in fact, more favorable than the morning period for many persons (Cf., also, Schuyten, *Paed. Jaarboek*, VII). The most satisfactory plan for giving proper weight to all the pertinent factors appears to be to put formal school exercises so far as possible in the forenoon, to use the afternoon for comprehensive, but not formal physical activity, and then, after a rest of half an hour to an hour, with nourishment, to devote the evening hours from 5 to 8 to mental work again, using this time for the pupils' studies, for reading, and for review and preparation of home-work—the abolition of which, as desired by many persons, including some teachers, would not be at all favorable to training in independent mental work; as even Kraepelin (*Ueberb.* 37) admits. From these considerations, there appears justification of evening schools for apprentices, for whom, as a rule, such courses are more of a recreation than an exaction of further effort (Schuyten).*

School program. These considerations of the value of forenoon and afternoon sessions and of the fatigue-value of the several studies are naturally of significance in the arrangement of the school program, as well as for the choice of the total number of periods, and particularly for the division of these periods. We shall have to try to put the most difficult subjects in the first two periods of the day, to put some easier subjects between difficult subjects, and to put gymnastics at the end of the forenoon session, or

*See, however, Winch, Some measurements of mental fatigue in adolescent pupils in evening schools, *Jour. Educ. Psychol.* I, 1910, 13-24, 83-100, where different conclusions are reached.—*Translator.*

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even better, to defer these until the afternoon, as had, indeed, been done, so far as feasible, in many places, before these questions were attacked by experimental investigation. One of the worst obstacles encountered in the attempt to make such arrangements is the system of departmental instruction.

Schiller (1897) was the first to try to adjust a school program in conformity with the results of experimental psychology. But it is clear that this was only a preliminary attempt, which did not, and could not, claim to afford an ultimate solution. The investigations of the fatigue-value of the several studies are still far from reaching results that are in any way conclusive. Nor can they ever afford us universally valid conclusions. Strictly interpreted, even when the difficulty of the fatigue-effect at different hours is obviated by making a large number of experiments, they are valid only for the average of a class actually compounded of good, average and poor pupils, animated by varied specific lines of interest. But this changes in proportion as this composition of the class changes by entrance or loss of pupils and in proportion as the pupils themselves change, for we must remember that their mental development does not, in any case, proceed with entire uniformity. Furthermore, the results must differ in other classes that differ in composition according to the endowment and propensities of the pupils. And it is well known, too, that the same subject is not equally difficult in every class—that, for instance, the geography of Germany, which is the assignment for the first and second classes of the *Gymnasium*, makes very much less demand on the pupil, at least when skillfully man-

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aged, than the geography of countries outside of Europe, which is assigned in the fourth class, and which is commonly compressed into a single year's work. So we cannot simply say: geography is less fatiguing than, perhaps, a linguistic study. Then, again, a school lesson is more exacting if the number of pupils in the class is small, because then the pupils are called on oftener and have to know their lesson better.

Fatigue-coefficient of the teacher. One more factor is to be noted that appreciably complicates the determination of the fatigue-coefficient of any study, namely, the fatigue-coefficient of the teacher. The more stimulating is a teacher's instruction, the more skillful he is in riveting the attention of his pupils, the more fatiguing is his instruction. The interest aroused by the teacher may banish the feeling of fatigue in the pupils, but, as Griesbach (*Intern. Archiv.*, V) properly remarks, this interest can as little remove the actual fatigue of the pupils as can the music of the regimental band banish the fatigue of a marching troop. This everyday observation has been confirmed by Wagner (*Unterricht und Ermüdung*, 115 ff.) by means of esthesiometric tests. And he is right when he estimates this factor as of more importance than the fatigue-value of the subject-matter. Moreover, a teacher who has little capacity for sustaining his pupil's attention can compel them to more active participation by harsh disciplinary measures. In such cases, the pupils exert their whole energy from fear.

Fatigue-coefficient of the method of teaching and learning. Besides the fatigue-coefficient of the

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teacher and that of the subject-matter, there is also a fatigue-coefficient of the method of teaching and learning. Thus far scarcely any attempt has been made to evaluate it; only Eulenburg and Bach (p. 1239) mention it. But it is evident that, even from the standpoint of the economy of mental force, it is not a matter of indifference whether I acquire certain information, *e. g.*, in the history of civilization, in botany, in physics, or in chemistry, by merely listening to a verbal description, or by reading about it, or by observation. Again, in the observation itself it is not a matter of indifference whether, in my consideration of the object or of the pictorial representation of it, I am guided by an accompanying description of the teacher, or whether I have quite by myself to pick out the essential features and separate them from the unessential ones. And it certainly makes some difference in the demands on mental efficiency whether a poem or a prose selection is learned by heart without adequate explanation of its meaning, or only after there has been gained complete understanding and adequate survey of the thing as a whole and after some emotional reaction has thus been awakened for the piece. Again, it will make a distinct difference whether a principle in physics has chanced to be worked out deductively and developed by mathematical formulas, or whether it has been discovered inductively by the introduction of experiments, whether the course of thought of a problem in philosophy, ethics, or natural science has been simply assimilated in a purely receptive manner, or has been developed by means of free exchange of ideas between pupils and teacher. These statements are,

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of course, only opinions. In general, the problems that are raised by them are, unfortunately, in large measure so complex in nature that their solution by experiment is still a far-distant matter. Meantime, we must rely for the working out of such problems entirely upon the keen sensitivity of the teacher who keeps watch on the effects of his teaching.

Individual instruction and class instruction. It is also clear that the economy of mental energy is different in individual, from that in class instruction, and that this difference plays a very decisive influence in the division of the subject-matter and the arrangements of the school program. Class instruction makes distinctly fewer demands on the attention of the pupils, for it permits those pupils who are not actually called on for recitation to work at half-attention. Kraepelin (*Geistige Arbeit,* 18) sees in this very fact a safety-valve, an automatic protective device against the over-exactions of the school. If, he means, the pupil were compelled to work at maximal attention during the whole school session, he would break down. But, as we have already asserted once before, class instruction does not really presuppose this. Because, if it could ever be brought about that the pupils followed the whole lesson with undivided attention, then we could certainly get on with a much shorter school session. Individual instruction demonstrates the truth of this statement. But, since the school cannot compel this intensive concentration of attention, it must extend the duration of the school day to make up for it. From the point of view of the teacher, however, the relations are just the reverse. For him, individual instruction is much less exacting

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than class instruction, which, as the class increases in size, demands that just so much louder speech and just so much more careful watching of the behavior and of the attention of the pupils be added to the task of teaching itself. The most exacting kind of school work, as is well known, is preparation for an examination; this Griesbach has demonstrated by tests with the esthesiometer.

Fatiguability of the teacher. This leads us now to speak briefly of the teacher, since we have thus far treated almost exclusively of the fatigue of pupils. We noted once before that fatiguability reaches its minimum, or mental efficiency its maximum, at the beginning of the twenties. If other conditions are favorable, we appear to remain in this stage some ten or fifteen years, often still longer. As we reach our fourth decade, efficiency slowly declines, and from the age of 50 on, this decline becomes quite manifest in many persons. From this, the conclusion may be drawn that the teacher—like every mental and physical worker—ought, as he grows older, to have his load lightened, not increased, as is at present so often the case; thus, for example, the teachers of the two upper classes (the two *Prima*), who are frequently the oldest of the staff, often have the hardest work—with the possible exception of the teachers of the fifth and sixth classes (the two *Tertia*). The opposite arrangement would be more rational from the standpoint of economy of energy. Basing their action on this same argument, the Austrian association of teachers of the middle schools has incorporated into their program a movement for the reduction of hours of service as the age of the teacher increases—a posi-

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tion for which Burgerstein (p. 721) has pleaded for a long time. It must be admitted that in Bavaria, as the work is now distributed, there can, in general, be no complaint that the teachers are overburdened, at least so far as the number of hours of required instruction are concerned. And it is not only the right, but the duty of those in charge of the schools to take proper steps to insure that the teachers do not exhaust their energies all too soon by giving extra instruction outside the required school hours. The maximal number of pupils for the middle and upper classes seems, however, to be too great, when we consider the labor of correcting the pupils' work, and this becomes particularly important in the cases, which are many, in which the regular enrollment is the maximal number allowed. In the matter of number of hours, only the teachers of the fourth and fifth classes are overloaded in schools in which, as is still quite often the case, they carry all the class instruction save that in mathematics.

But even when the maximally permissible number of hours are not assigned, the academically trained teacher nevertheless finds that his capacity for work is well taxed, more so than in most other academic callings. Here, as ever, exceptions prove the rule. Unstinted praise belongs to H. Schröder for having proved incontestably by statistical inquiry that the notion that the teacher, on account of his constant association with youth, rejoices in unusual vitality is a naive fable, that, as a matter of fact, the academically trained teacher, in particular, exhausts his powers sooner than do other officials of like training, and that his liability to disease and his mortality exceeds

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that of other public servants. Subsequent inquiries have showed that he was right. The teacher of the *Volksschule* works under still more unfavorable conditions.* From a purely business point of view, therefore, the teacher's capacity to work should be economized, to the end that it may be rendered available for longer service. To say nothing at all of the enormous importance for the success of teaching and education that the teacher shall confront his pupils with perfect freshness of mind and spirit, not with the irritability and ill-humor of a neurasthenic.

*Cf. R. Wichmann's lecture on the health of teachers in the *Verhandlungen der VII. Jahresversammlung des deutschen Vereines für Schulgesundheitspflege*, 1906, at Dresden, also the *Ergänzungsheft* to *Gesunde Jugend*, VI, 1906, 27 ff., and the very noteworthy chapter on the hygiene of the teacher in Burgerstein, 718 ff., as well as L. Wagner's comments in his translation of M. V. Manacéine's *Le surmenage mental dans la civilisation moderne*.

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CONCLUSION

There are many other questions that may be raised in connection with this subject. And we might attempt, in summarizing, to work out a unitary theory of fatigue. But this would be possible only by discussing the general energetics of mental life, the general theory of the forces operative in our psychical life, their amounts, their origins, their consumption, and the laws of their interaction. We have been led, indeed, to do this on more than one occasion, as, for instance, when—in our earlier presentation of the problem of memory along Lippsian lines—we made use of the concept of mental energy and its supply, and when we said of it that it increases with rest and nutrition, but is used up during work. But it would lead us farther into the field of psychological theories and hypotheses than would fit the purpose of the present discussion were we to pursue these considerations any longer.

Is it permissible that pupils be fatigued? But we must first answer another question of importance to the teacher. *Is it permissible that pupils should be fatigued by work, or more exactly, since there is no work of any sort that does not fatigue, is it permissible that pupils should be held to their work so long that positive signs of fatigue, especially weariness and reduction of work, appear?*

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Perhaps this question will be answered by an anxious negative, for fear lest the youthful nervous system might otherwise suffer injury, and it will be certainly pointed out that the work that is done under the stress of oncoming fatigue is surely of less value.

We need not be too anxious, even if we do not stop to note that a piece of work done, though it may be inferior to some other, is nevertheless better than none at all. So long as the youthful worker, by dint of adequate nutrition and abundant rest, especially plenty of sleep, regains every morning his capacity for, and pleasure in, work, so long there is no danger, and we may unconcernedly let him work till he is fatigued. Only, we should not neglect at the same time to make clear to him the significance, as a protector of his health, of the feeling of weariness, and to train him in this way to restore his powers and to recuperate his energy rationally.

But I go farther than this. We may, indeed we ought, off and on, to let him work a good bit under the pressure of fatigue. We ought, now and then, to induce him to take himself in hand and to draw on all his reserve strength, so as to force him, as a test of power and strength of will, to do more than he ordinarily does. Often enough, our life brings us into situations where we have to put forth more than our customary effort—situations that oblige us for some time, and unfortunately often for no short time, either, to turn a deaf ear to the kindly warnings of that faithful guardian of our health.

A man must be trained to meet such situations as these, too. He must learn by his own experience how much strength he has laid by, in saving, for emergen-

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cies; but he must also learn as well how to expend this reserve prudently, and how he can restore it once more. To learn the first lesson brings him assurance and consciousness of power; to learn the second deters from foolish use of his reserve capital. To shield the pupil from these tests of strength is to rear him in weakness and timidity. And in this sense, we agree with Zielinski when he says: "An easy school is a social crime" (see Höfler, 39 f.).

In the same way, physical training develops in the growing being the capacity for resistance that is requisite for life, not by timidly sheltering him from the harshness of the elements, but by gradual habituation to them, by a process of hardening. In this physical training, he is compelled—not every day, but from time to time—to undertake trying marches and fatiguing athletic games, to endure thirst and hunger, heat and cold, weariness and pain of limb, to exercise self-control by deferring the gratification of his desires (perfectly justifiable intrinsically) until the resting place has been reached, the journey's end attained. Then, to be sure, he is allowed to restore himself, but he is taught, even then, to choose the proper kinds of food, to observe moderation, and to take his repose in a rational manner. And if we do this systematically and with due deliberation, if we bring up our youth to proper care of their bodies, more by strict training than by fine talking, we know that we are thereby doing them a greater kindness than if, out of weak sympathy, we had let them give heed to every trivial call of their bodily needs.

Training in mental hygiene. Now, training in mental hygiene must follow precisely the same plan,

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if it is to train up hardy and persistent workers, and not dawdling weaklings, in the fields of mental effort. It must occasionally exact a hard bit of work of the youth. It is to be assumed, however, that it will make these demands of him only when it can afford him a proportionately longer time for subsequent rest and recovery, and when, moreover, it teaches him methodically how the stint that is set may be done with the available amount of strength, and how he may work most economically and with maximal profit. This kind of training in mental hygiene is peculiarly necessary in these days, when large numbers of our youths, especially in the cities, no longer bring with them to the school the same unweakened nervous energy that our father and grandfathers displayed, when life outside the school makes greater demands on the pupils than formerly, and when, too—we must not deceive ourselves on the point—the requirements of the school, despite the fact that many a grammar has become thinner, are certainly not less, when they are all fully satisfied, than they were forty or fifty years ago. For our school work today, as Keller rightly declares, is less restricted and unitary, and to be sure less monotonous, too, but rather of a kind to appeal to more varied interests; it is richer in content and more intensive in treatment, since it proceeds less mechanically, less by mere passive reception, but impels the entire person to greater activity.

More intensive physical development. In point of fact, the school cannot stop short at this training in mental hygiene. It will ultimately be compelled in some measure to reduce its scholastic requirements, in order to give an opportunity for a serious and sys-

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tematic plan of physical development. For it cannot be denied that our cultured classes are now retrograding physically, and this means that ultimately they will lose in mental efficiency as well. The school is certainly much less to blame for this condition of affairs than people are apt to think. Only an exceptionally strong nervous system can withstand our complex life, ever becoming more intensive, the demands of our professional and our public career, as well as the manifold claims arising from other aspects of our life—claims that we might avoid if we wished, but to which we tend more and more to give way from lack of moral force to decline them. Most of us suffer, and our nervous vigor is seriously impaired by this stress of life.

Nor is this all. The weakness of the parents is handed down as a handicap of inheritance to the children. These are facts to which we cannot close our eyes. Rather must we keep the situation clearly before us, and use every endeavor to better faulty conditions.

The edict of the Bavarian ministry of public instruction, which, several years ago, required the cultivation of athletic games, has shown the right road. We need only keep on in this direction. We must make participation in games a duty, so that no pupils, at least none of those who need them most, the weaklings, can fail to take part in them. And we must make room for such games in our school program by reducing the demands for intellectual work, so that even the most industrious and conscientious, who are the very ones that stand most in need of a counteractant to their mental effort, shall be able to indulge

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in games with an easy conscience and with no lack of enthusiasm.*

Finally, we must undertake seriously to *revise our views of the relation of bodily and mental work.* We must reach the conviction that bodily life and mental life are not separate systems, but that they spring from the same sources; that they do not keep separate accounts, like married folks who divide their goods, but work together, like husband and wife who hold the funds in common, when whatever the one takes out of the bank is no longer at the disposal of the other.

If this exposition assists teachers to a fuller understanding of the close connections between the two sides of our human nature and of the limits of their efficiency, and if it stimulates them to make application of this understanding, it will have served its purpose.

*On the lack of adequate participation in athletic games, consult Dörnberger (*Dtsch. Med. Prax.*, 13) and Grassmann (p. 170), who demands compulsory participation to remedy this faulty condition.

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(For selected English references, see Appendix I, below).

Key to Symbols.

A. G. P.—Archiv für die gesammte Psychologie.
A. J. P.—American Journal of Psychology.
A. J. Ph.—American Journal of Physiology.
A. P.—Année psychologique.
Ar. P.—Archives de Psychologie.
I. M.—International Magazine of School Hygiene.
I. K.—Internationaler Kongress.
J. E. P.—Journal of Educational Psychology.
P. A.—Psychologische Arbeiten.
P. J.—Paedologisch Jaarboek.
P. R.—Psychological Review.
P. S.—Pedagogical Seminary.
Ph. S.—Philosophische Studien.
S. Z.—Schiller-Ziehen, Sammlung von Abhandlungen aus dem Gebiet der pädagogischen Psychologie und Physiologie.
Z. P.—Zeitschrift für Psychologie und Physiologie der Sinnesorgane.
Z. P. P.—Zeitschrift für pädagogische Psychologie.
Z. S.—Zeitschrift für Schulgesundheitspflege.

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APPENDIX II.

The Terminology of the German School System.

No attempt has been made in the translation to find English equivalents for *Volksschule*, *Gymnasium* and other types of German schools, because there are no exact English equivalents. A brief explanation of the German school system is therefore in order. Each German state has its own system, yet there is a general similarity of organization. The Prussian system may be taken as typical. In that state, what would correspond to our public schools are divided into two sections, which are often termed the elementary and the secondary schools, respectively, though these designations convey the false idea of an 'educational ladder,' like our own system, that does not exist in Germany.

The elementary schools include the *Volksschule*, the *Mittelschule* and the *Fortbildungsschule*. These three schools serve to train children of the laboring or lower business classes. Attendance in the *Volksschule* is absolutely compulsory from six to fourteen years, unless the child is otherwise instructed. The *Mittelschule* includes instruction in French and English, exacts a moderate tuition fee, is patronized by the lower middle classes, and hence draws pupils of better ability and home training. The modern *Mittelschule* may be considered a substitute for the earlier *Bürgerschule*. The *Fortbildungsschule* (continuation school) is a short course, required or optional, giving vocational and industrial instruction to pupils who have finished the *Volksschule* or *Mittelschule*.

The higher or secondary schools include the *Vorschule* and various types of *Gymnasium* and *Realschule*, as well as the *Höhere Mädchenschule* or *Töchterschule*. The *Vorschule* is virtually an elementary preparatory school, entered at six, and turning its pupils into higher schools proper at the age of nine. Practically all German children destined for higher education use the *Vorschule* in place of the *Volksschule* or *Mittelschule*. Of the higher schools proper, the *Gymnasium*, the *Realgymnasium* and the *Oberrealschule* represents three co-ordinate, but independent, institutions, each with a prescribed nine-year curriculum. Pupils commonly enter, then, at nine, and are graduated at eighteen, so that the course virtually includes the first two years of the ordinary American college. Pupils may, subject to geographical limitations, elect the type of school, and may in theory elect certain optional supplementary work in them, but in practice, the required work is heavy enough for most pupils. The nine classes, beginning at the last, or senior, year are known as *Oberprima*, *Unterprima*, *Obersecunda*, *Untersecunda*, *Obertertia*, *Untertertia*, *Quarta*, *Quinta* and *Sexta*, respectively.

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The *Reformgymnasium* and the *Reformrealgymnasium* have practically the same curricula as the *Gymnasium* and the *Realgymnasium*, only so arranged that the pupil need not decide finally upon his course of study until the age of twelve, instead of at nine.

The *Progymnasium*, the *Realprogymnasium* and the *Realschule* are three schools, corresponding to those indicated by their names, but offering only six of the nine years' course; they are found oftenest in smaller cities that cannot afford the nine-year courses.

The *Höhere Mädchenschule*, or *Töchterschule*, is a ten-year school for girls (thus allowing them one year more than boys) and covering as a rule the ages six to sixteen. A very recent movement (since 1908) provides for the enlargement of these courses by the addition of three more years, which will give girls an education equal to that offered boys.

For a description of the *Frauenanstalt*, or school for women, and the *Lehrerinnenseminar*, or normal school for female teachers, as well as for further details concerning the schools mentioned above, the reader may consult J. F. Brown, *The Training of Teachers for Secondary Schools in Germany and the United States*, Ch. I.

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